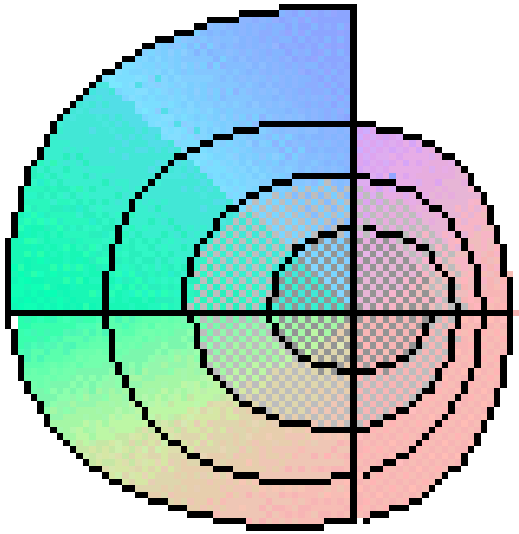
Evolutionary Acquisition Presentation for NASA



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Workshop Outline

- Overview and Definitions
- Changes in Requirements Generation and Acquisition
- IPPD
- EA and Systems Engineering
- Architectures
- Open Systems
- Assessing Technology Readiness
- Technology Cycles
- Risk Management/Mitigation
- Metrics
- Cost Estimating
- Applying Evolutionary Acquisition
- Getting Help

Relationship of EA to SD and ID

- Evolutionary Acquisition is an *acquisition strategy*
- Spiral Development and Incremental Development are *development processes* or *methodologies* in which a product is developed and acquired in increments vice the complete system.
  - Which process is used depends on whether the requirements are known up front.

Spiral Development Background

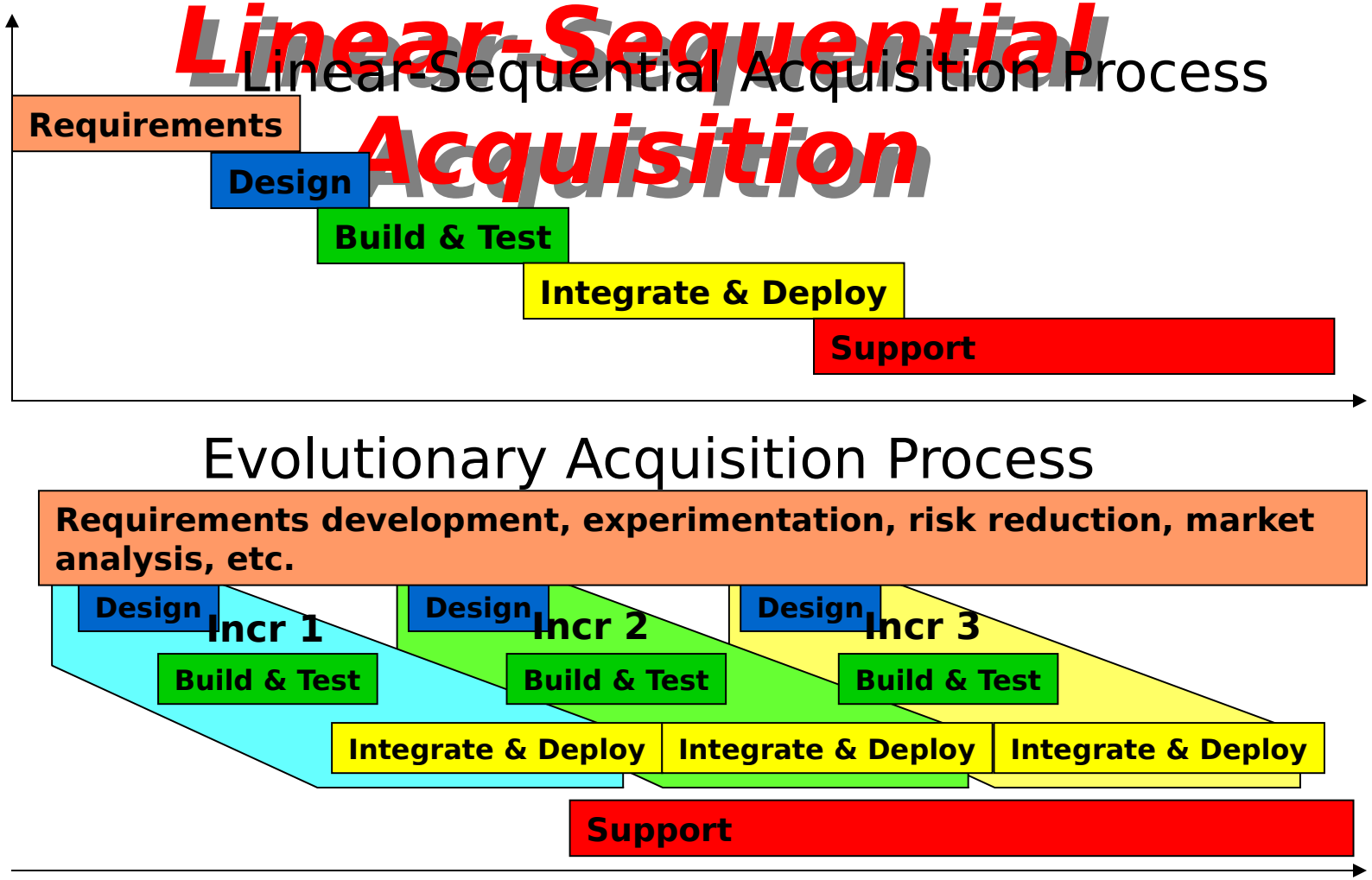
- First articulated by Barry Boehm in1988
  - Generally accepted, recently refined:

"The Spiral Development Model is a **risk-driven** process model generator for guiding **multi-stakeholder** concurrent engineering of software-intensive systems. Its distinguishing features include a **cyclic approach** for **incrementally** growing a system's degree of definition and implementation, and a set of **anchor point** milestones for ensuring feasibility of the incremental definitions and implementations"--Boehm, *"Spiral Development - Experience and Implementation Challenges"*, CMU/SEI-2000-SR-006 February 9-11, 2000, Page 9.

[Emphasis added]

  - Spiral Development came out of the software community as a response to the high number of large software development failures

Evolutionary Acquisition versus Linear-Sequential Acquisition



Evolutionary Acquisition Characteristics

- General description of desired full system functional capability
- Concise statement of full system operational concepts
- Flexible overall architecture allowing incremental design
  - Use of Open Systems Architecture is one method
- Plan to incrementally achieve desired total capability
- Early definition, funding, development, testing, supporting and operational evaluation of initial increment of operational capability
- Continual dialogue and feedback among users, developers,

Incremental Development

- Incremental Development (ID) definition
  - In this process, a desired capability is identified, **an end-state requirement is known**, and that requirement is met over time by development of several increments, each dependent on available mature technology.

[Emphasis added]

DoD Instruction 5000.2 *dated May 12, 2003.*

Incremental and P3I

- Pre-Planned Product Improvement (P3I) has long been used for development
  - P3I has traditionally been used to insert capabilities or subsystems that were not ready in time for deployment
- Incremental development goes beyond P3I
  - Defer to later block for technologies that will not be ready
  - Defer to accelerate delivery of first block of capability
  - Defer to reduce cost

Incremental Example

F/A-18 E/F Super Hornet

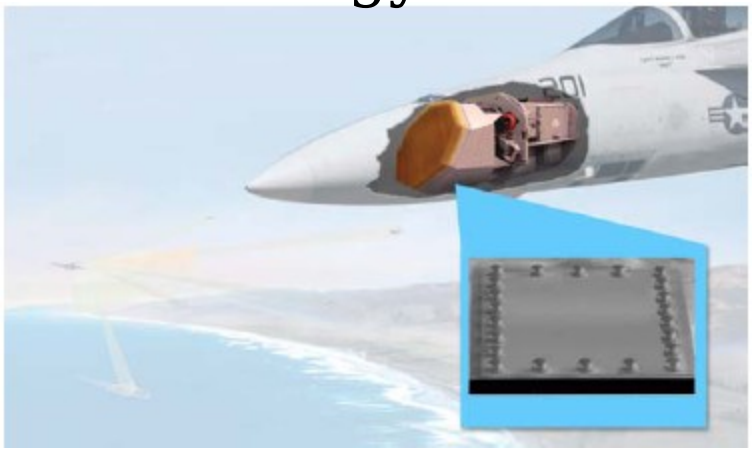
Incremental Development

- F/A-18 E/F Super Hornet
  - Low Risk Approach
    - Immature technologies deferred to later increments
  - Allowed earlier delivery of initial system
  - Incremental Improvements
    - Advanced Tactical FLIR
    - Active Electronically Scanned Radar
    - Helmet Mounted Cueing System
    - Engines Upgrade
    - Integrated Defense Electronic Countermeasures
  - F-18G “Growler” in Development

AESA Radar Development

Commercial Radar Technology

Conventional Radar



Electronic Scan Radar

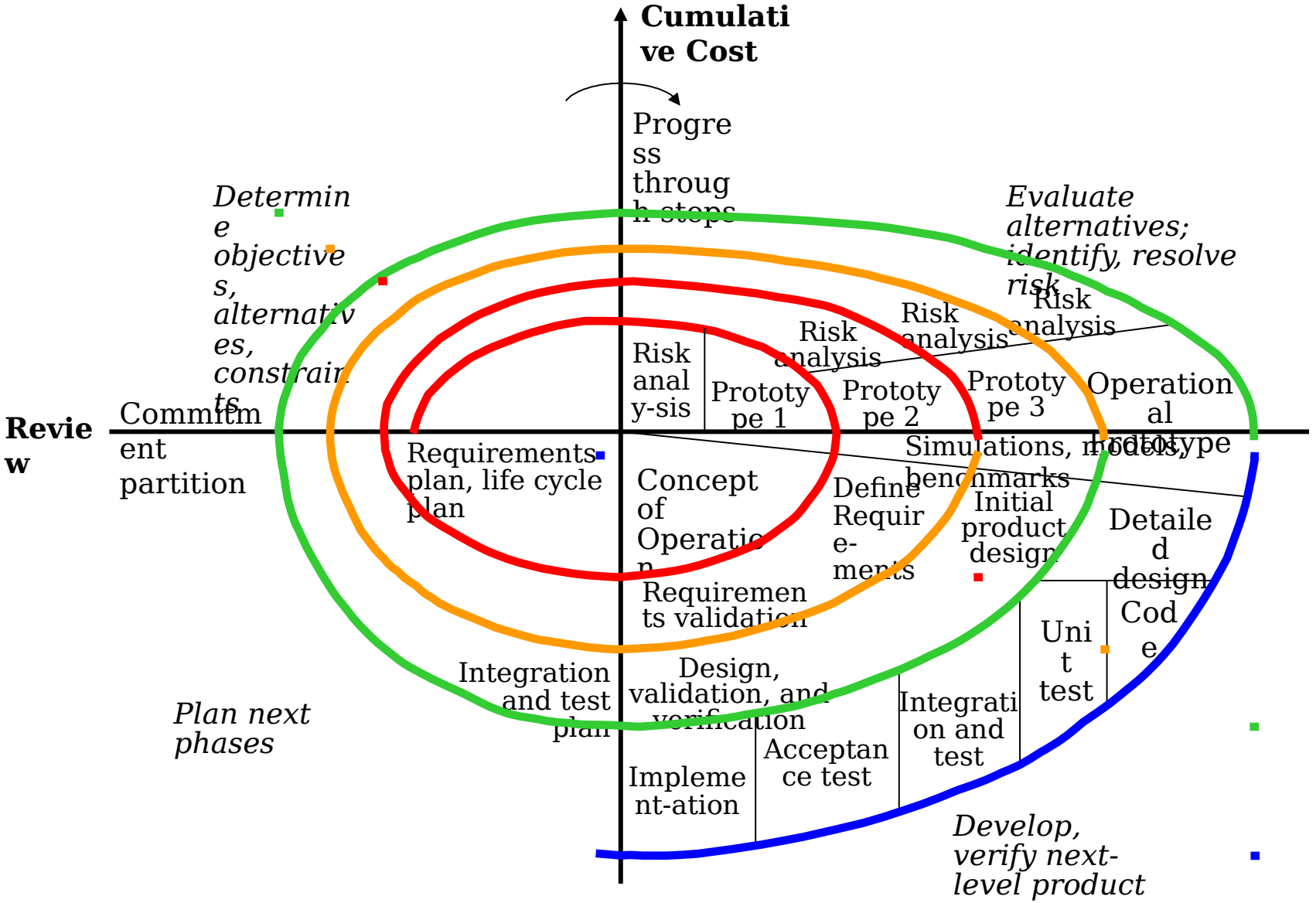
Spiral Development

- Spiral Development (SD) definition
  - In this process, a desired capability is identified, but **the end-state requirements are not known at program initiation**. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation.

[Emphasis added]

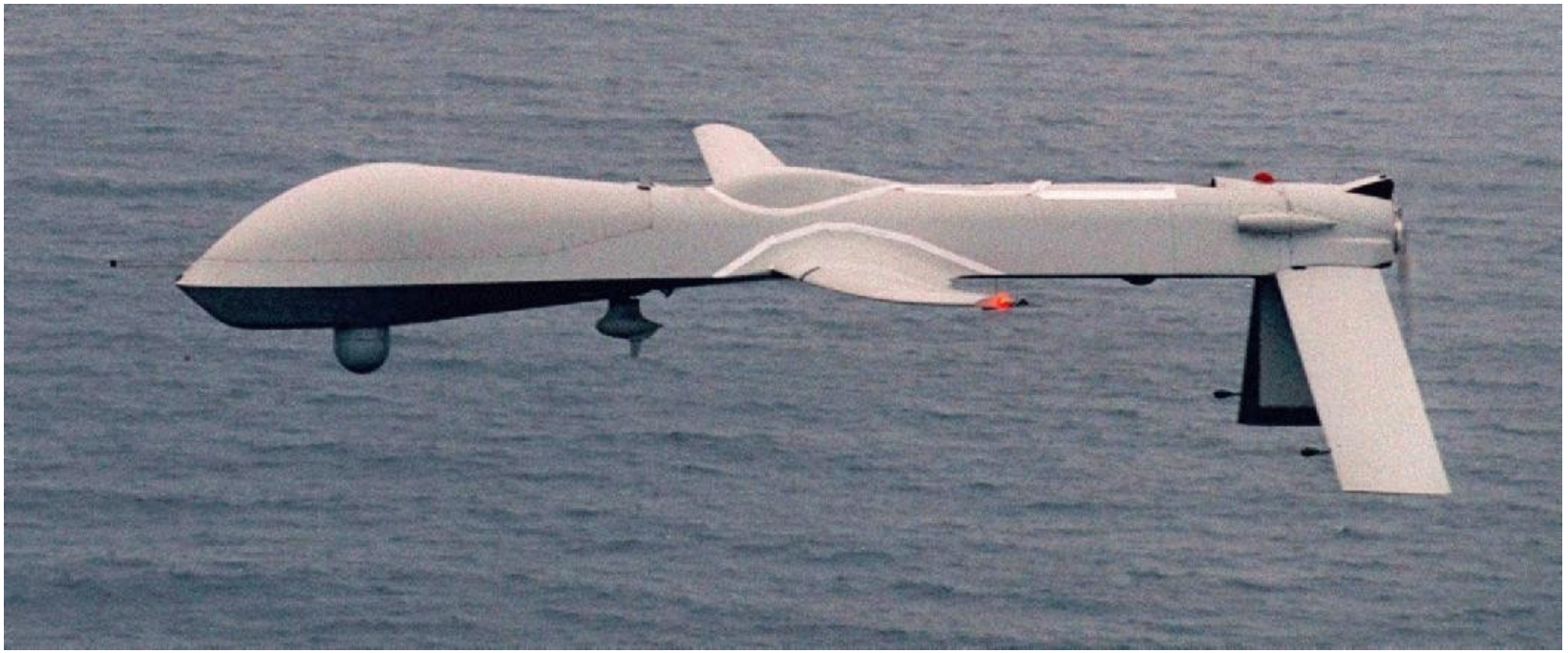
DoD Instruction 5000.2 *dated May 12, 2003.*

Spiral Development Model*



*Reference: "The Spiral Model as a Tool for Evolutionary Acquisition" Crosstalk -The Journal of Defense Software Engineering, May 2001; Dr. Barry Boehm

Spiral Development Example



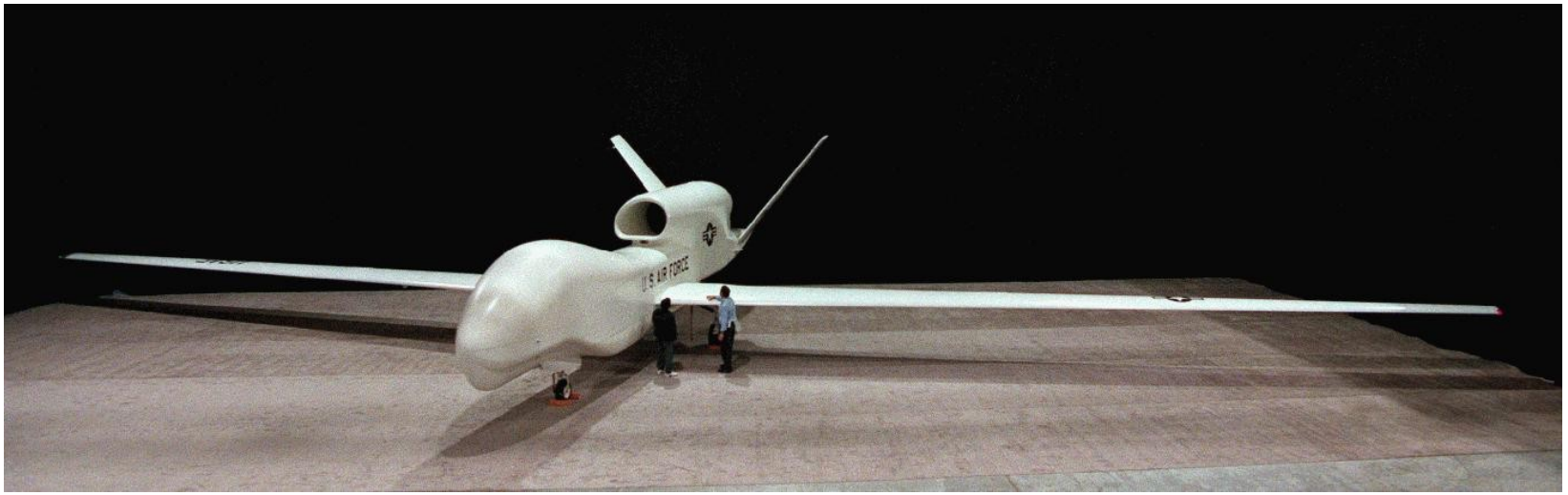
RQ-1 Predator UAV

Spiral Development Example

- Predator UAV
  - Developed as an Advanced Concept Technology Demonstrator
  - Initial requirement for unmanned aircraft to provide real-time reconnaissance
  - As a result of operational use, new requirement to strike time critical targets
    - Armed with Hellfire missile
    - Can carry laser designator
  - Further improvements in work as the result of operational feedback are improved engines, sensors and increased payload
  - Lessons learned from Iraqi Freedom?

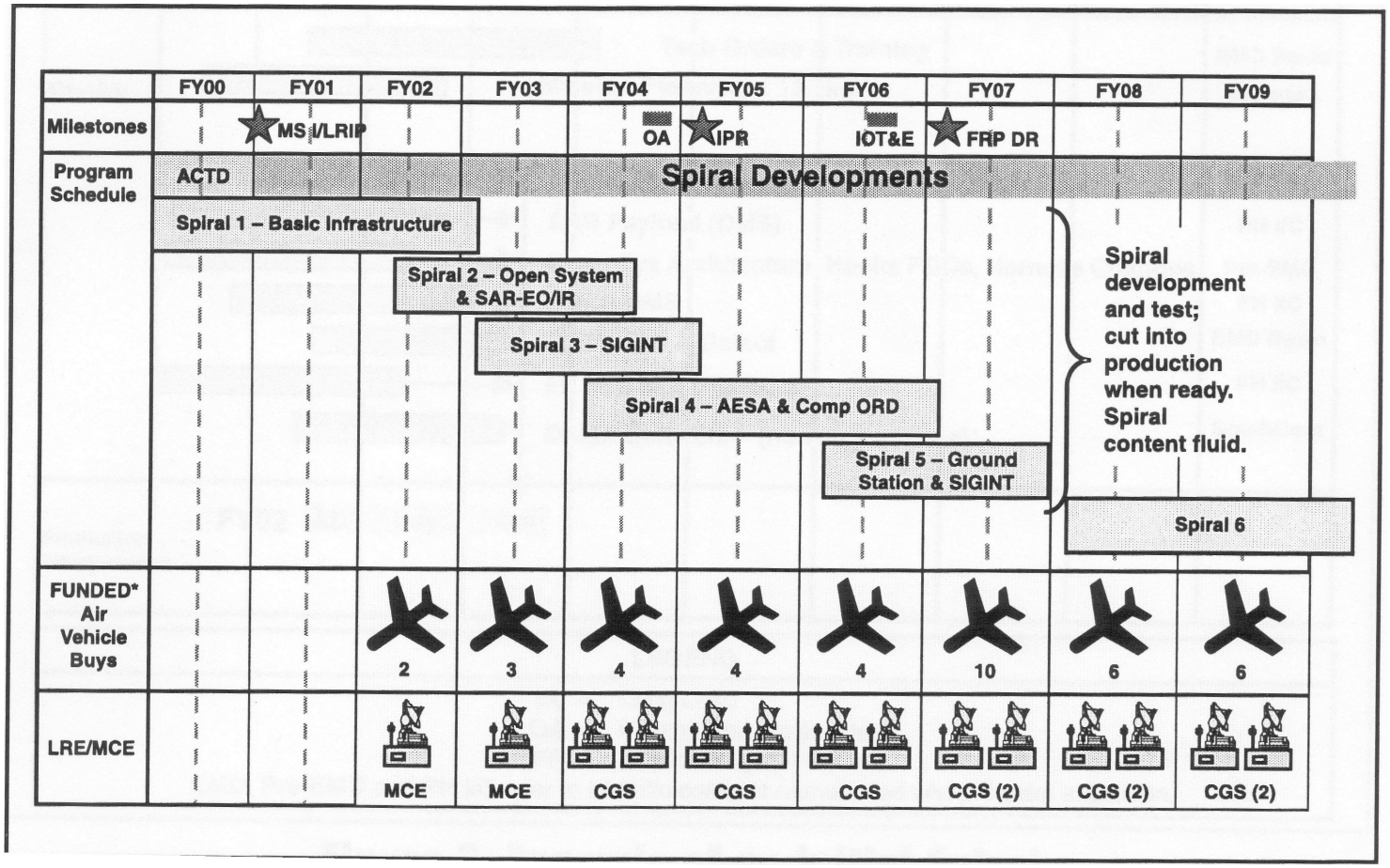
r difference is that an initial capability was delivered w
uirements for upgrades were generated by feedback fr
operational use

Spiral Development Example



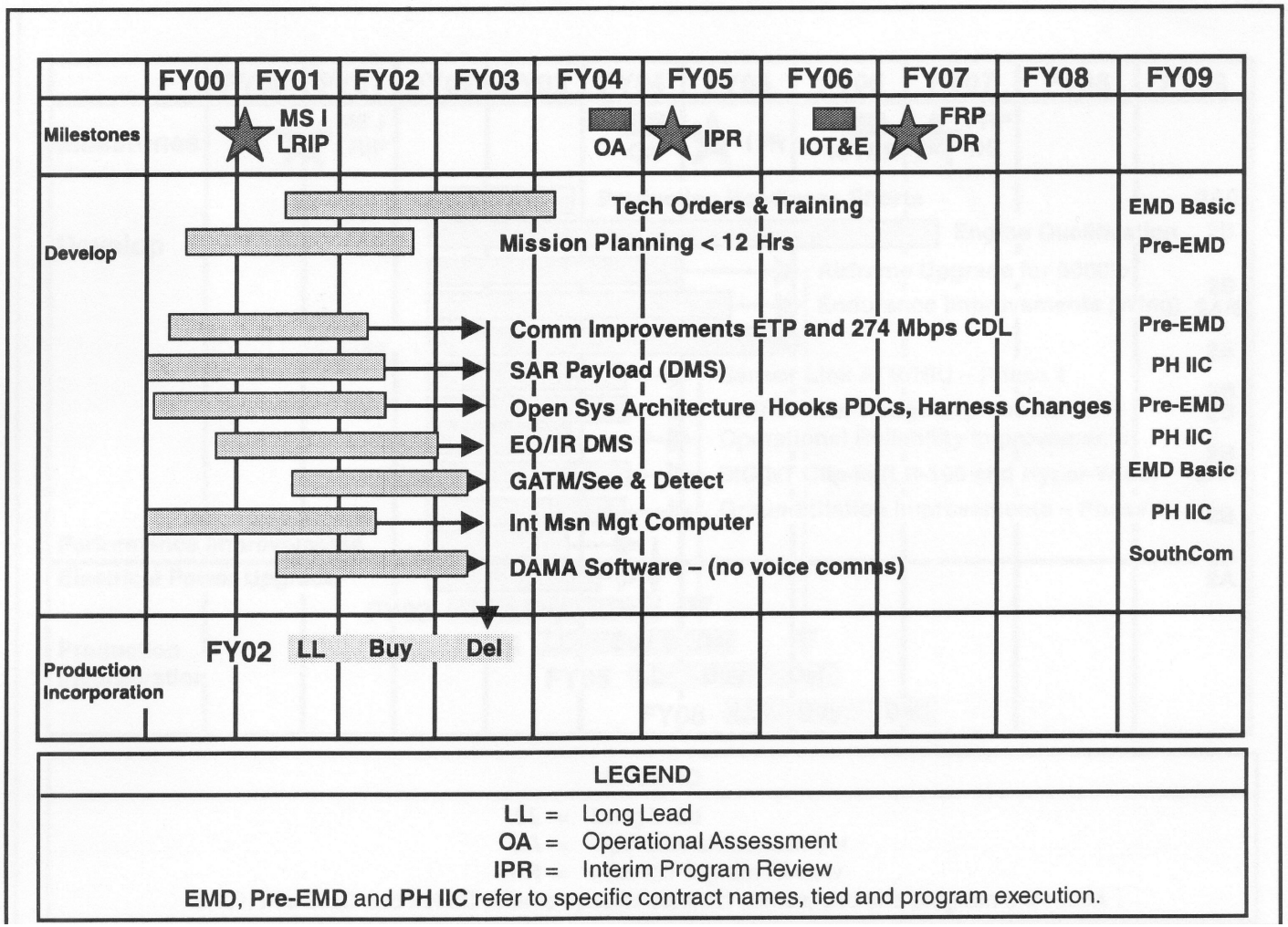
RQ-4A Global Hawk

Global Hawk Spirals



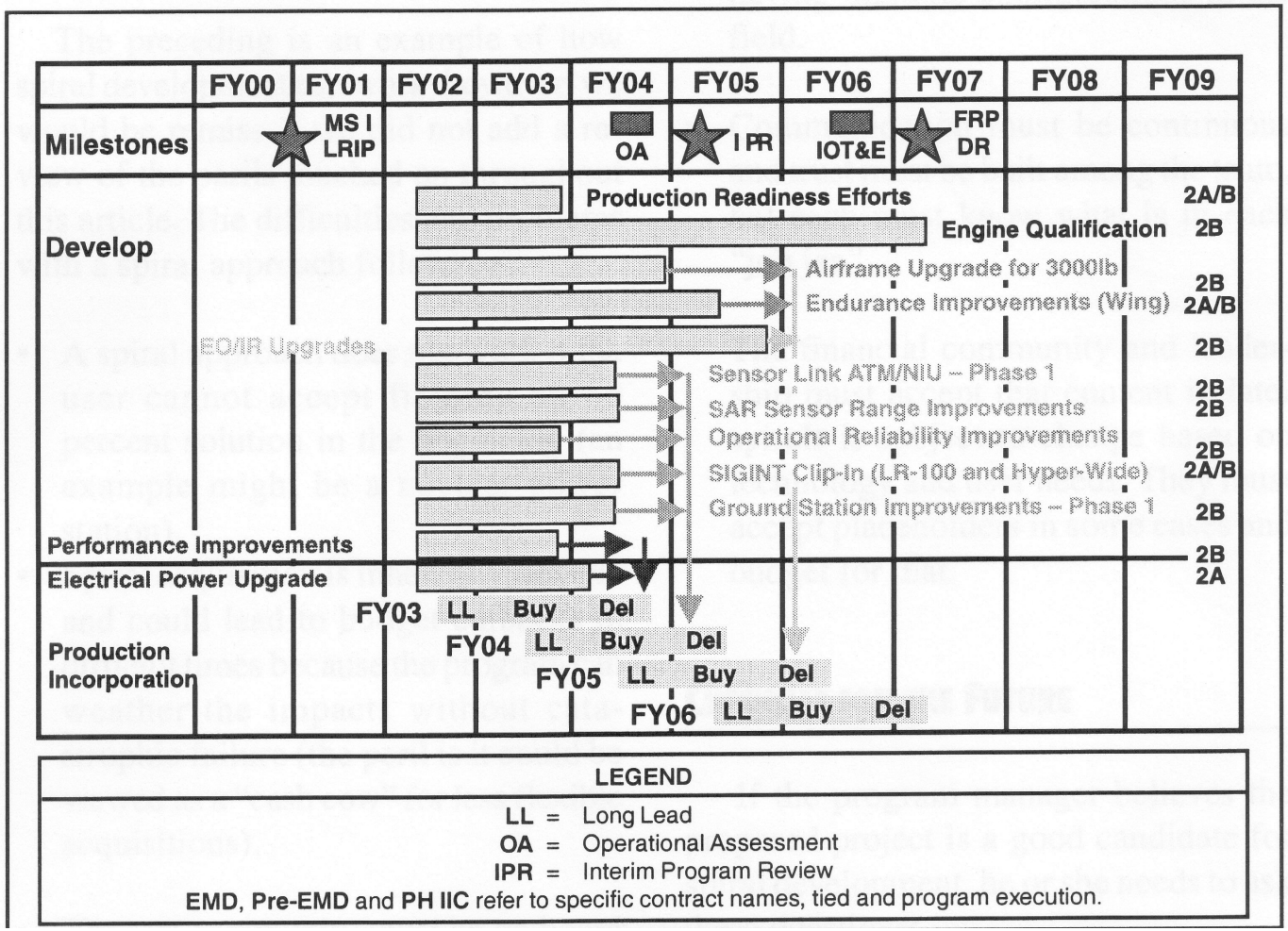
Johnson, Col Wayne and Johnson, Carl, *The Promise and Perils of Spiral Acquisition: A Practical App*
Acquisition, Acquisition Review Quarterly, DAU Press, Summer, 2002

Global Hawk Spiral #1



Johnson, Col Wayne and Johnson, Carl, *The Promise and Perils of Spiral Acquisition: A Practical App*
Acquisition, Acquisition Review Quarterly, DAU Press, Summer, 2002

Global Hawk Spiral #2



Johnson, Col Wayne and Johnson, Carl, *The Promise and Perils of Spiral Acquisition: A Practical App*
Acquisition, Acquisition Review Quarterly, DAU Press, Summer, 2002

Advantages of Spiral Development

- Spiral development is designed to be more responsive to user needs
  - Shorten turn around time for emergent user needs
  - Focus on the most critical user needs at the current time
  - Avoid developing things the user may have thought they needed, but later discovered were not that critical.

User Issues

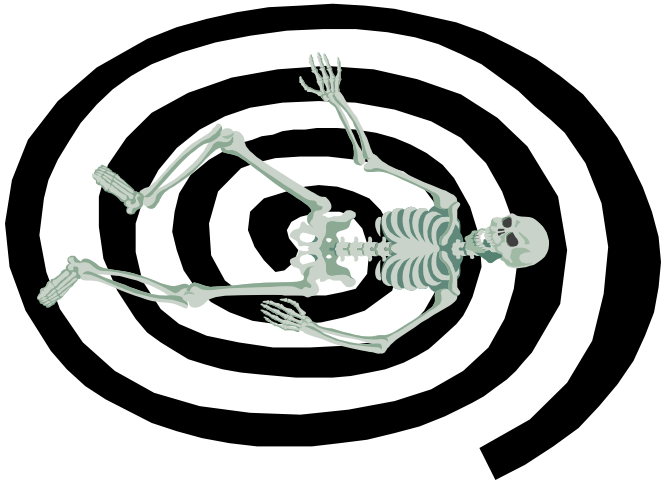
- Acquisition Community must prove they can deliver under this new process
  - Must deliver what is agreed to when it is agreed to
- In the past, people and resources fall dramatically when a system meets IOC
  - Under an evolutionary approach, up to 40% of the capability may still be in some stage of development
  - Follow-on blocks must receive the same priority and commitment as the first

Past Performance

- Evolutionary acquisitions have not had a good past history
  - F-14 Tomcat IOC in mid 1970s
    - Deployed with the TF-30 engine as an “interim” solution due to F-100 engine development problems
    - Successfully deployed the AWG-9 weapon system for fleet defense
    - Numerous engine related accidents
    - Began replacement of TF-30 with F-110 in the late 1980s
    - It took about 25 years to replace the “interim” solution

Avoid "The Death Spiral"

- A cascading deferral of planned functionality
- Occurs when insufficient accommodation is made for unplanned growth in development effort
- Three basic causes
  - Unanticipated requirements growth
  - Unanticipated support cost growth for early increments
  - Unanticipated implementation challenges



Hybrid Strategies

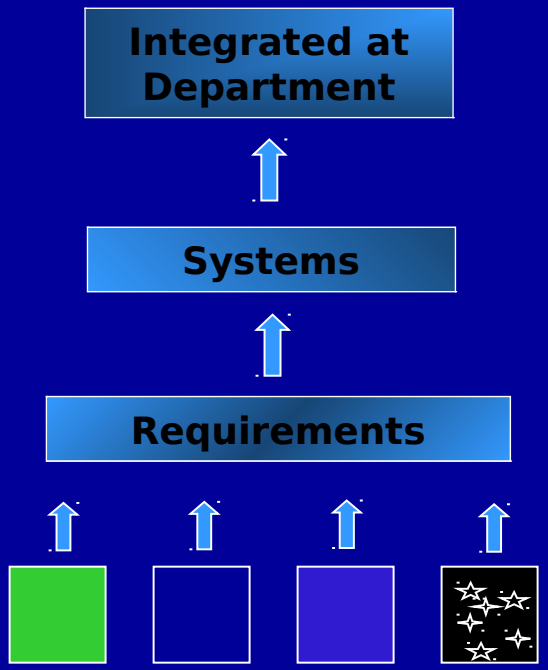
- It is possible to mix incremental and spiral development in the same acquisition
  - Computer example
    - Computer is on sale but new flat screen monitor is not
      - Incremental strategy
        - » Buy computer, use old monitor
        - » Purchase flat screen monitor in future at lower price
      - Spiral strategy
        - » Purchase computer with empty drive bays and card slots
        - » Add new technologies as they become available

Force Transformation

- Spiral Development also supports rapid development of new ways of fighting
- Current acquisition system generally develops requirements for new systems based on how we did things in the past, not how we will do things in the future
- Example
  - One part of the problems with the A-12 was the requirement to carry the entire bomb load of an A-6, the aircraft it was to replace, internal to the aircraft
  - This was based on tactics used in Vietnam and ignored the rapid emergence of precision guided weapons that were already in use at the time

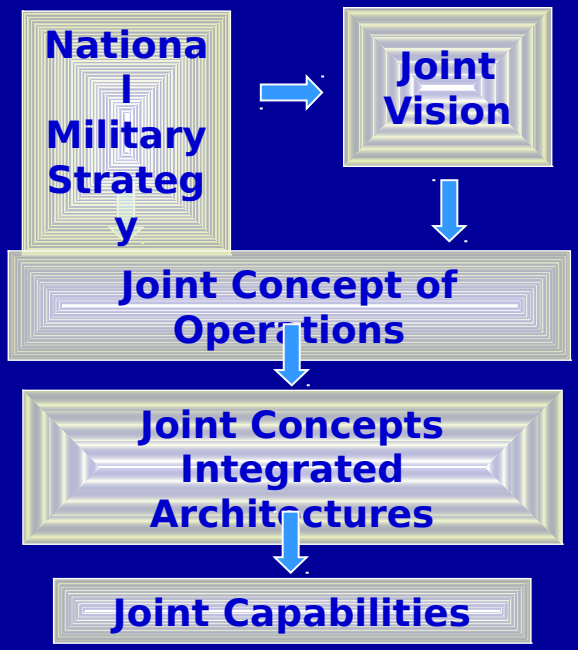
Transformation to the Joint Capabilities Integration and Development System

RGS



Bottom Up, Often Stovepiped

JCIDS



Top Down, Born Joint

Requirements & Acquisition Process

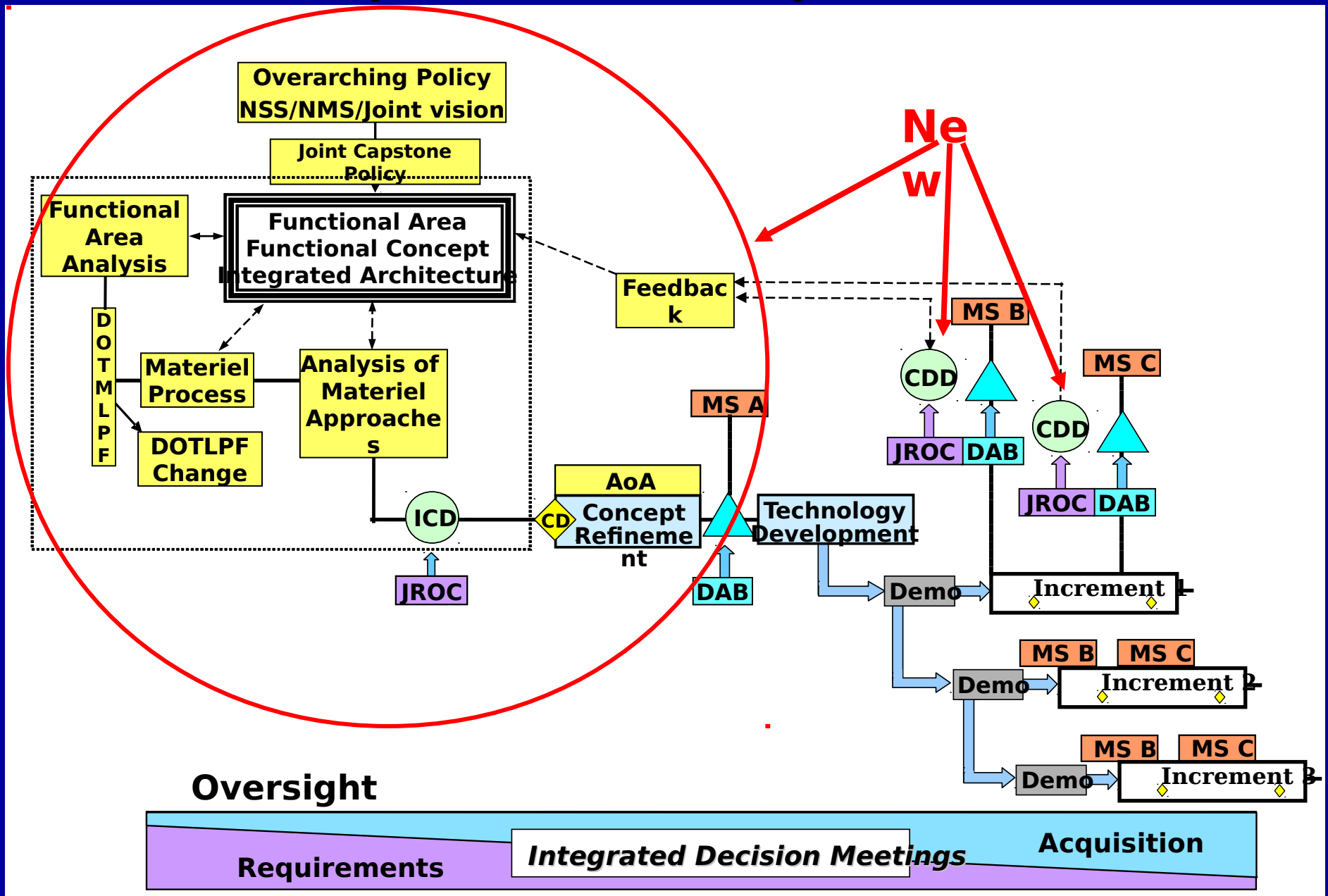


Fig. 2, DoDI 5000.2

Integrated Product Team Definition

- A multifunctional team assembled around a product or service.

- Responsible for advising the team leader… on cost, schedule, and performance.

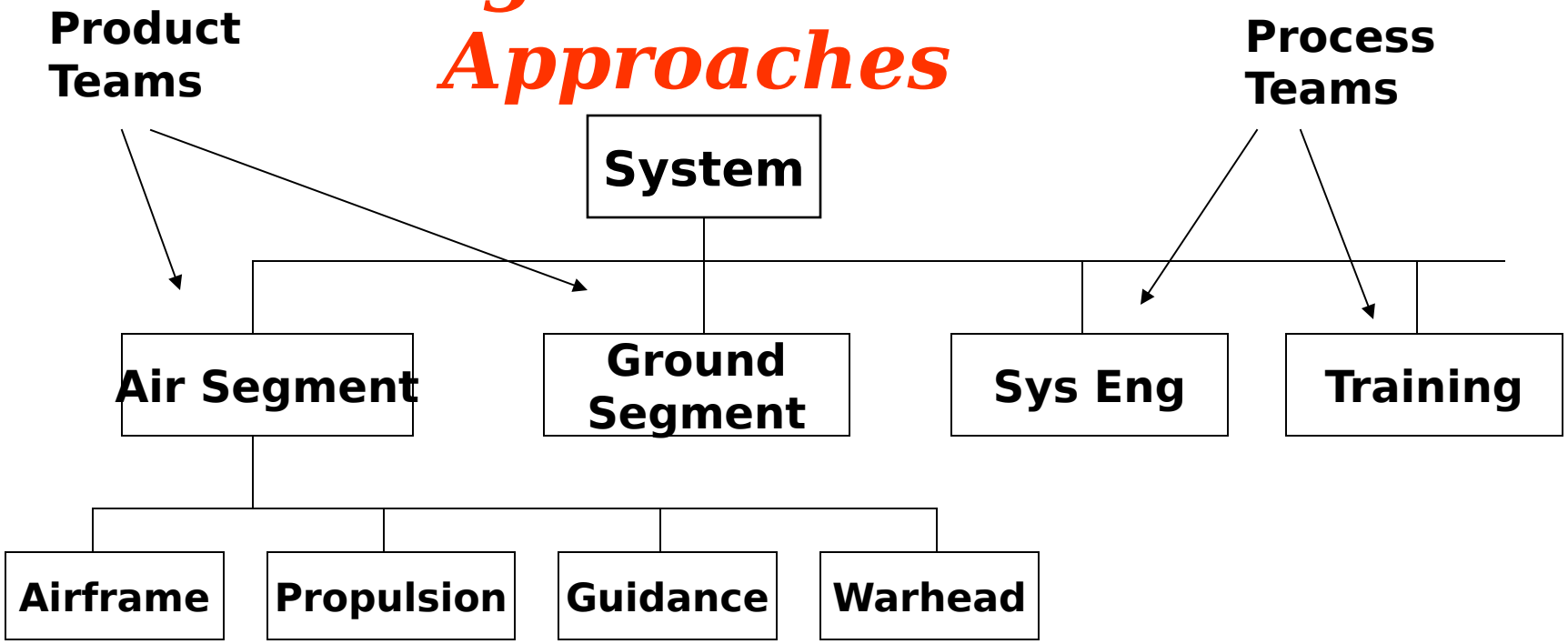
Issues in IPT Management

- **How to Organize**
- **Integration across teams**
- IPT management (leadership, informal vs formal organizations)
- Role of functional Managers
- Career development while assigned to teams
- **Changing focus by Acquisition Phase**
- Problem team members

The Integration Challenge

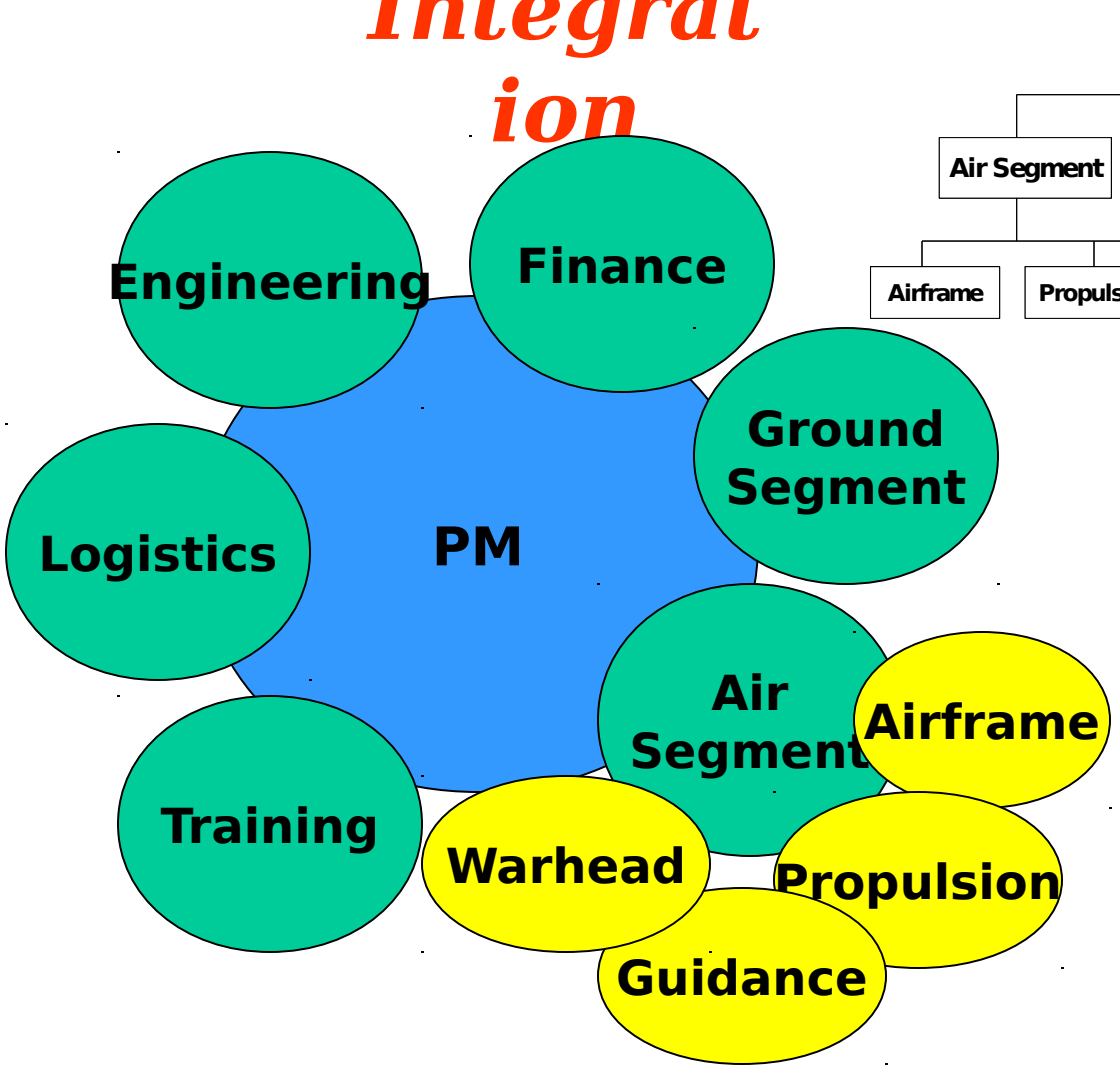
- Among the issues associated with managing IPTs are these:
  - How does the manager ensure that information flows across IPTs within a given program?
  - How does the manager ensure that lessons learned from one program flow to others under his/her cognizance?

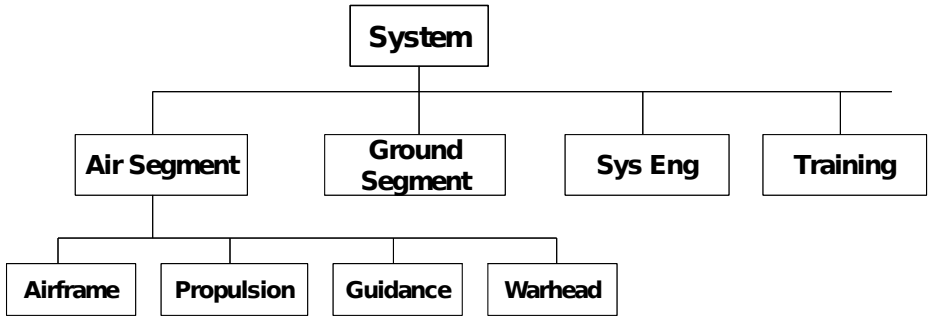
Integration
Organizational Approaches



Problem: How to integrate teams so that all have needed inf
and all work toward common goals?

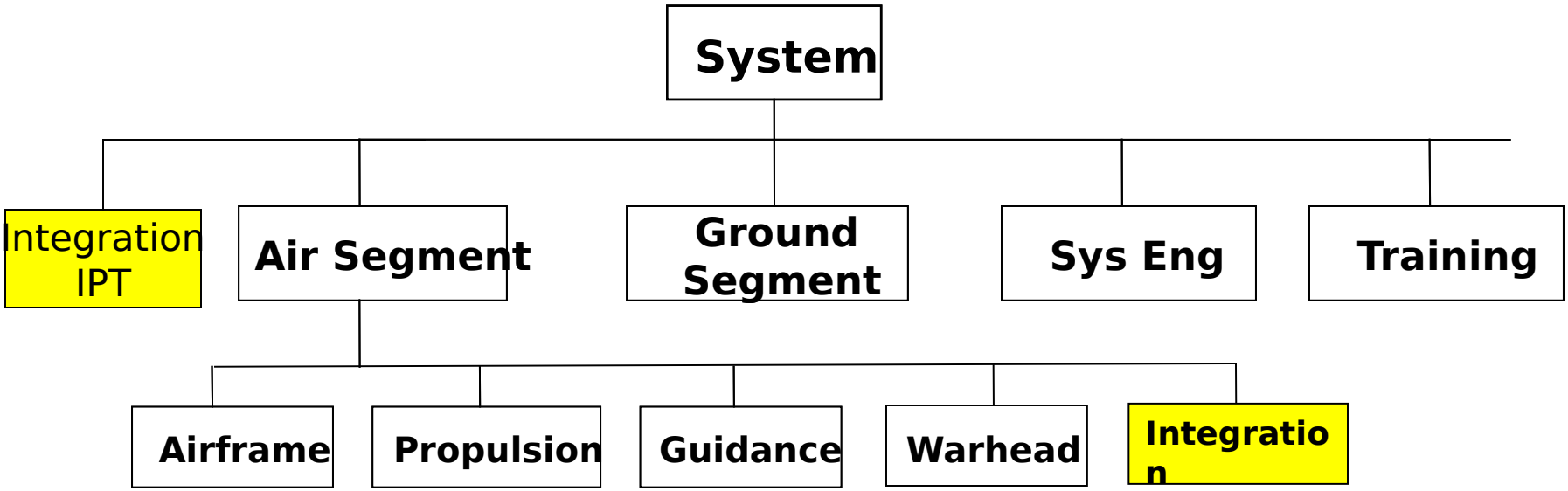
Integration





A common approach is the development of clustered teams where each function/product is represented on the next highest level team

Integration



Another common approach is to designate “Integrating IPTs” whose responsibility it is to ensure information flows between teams

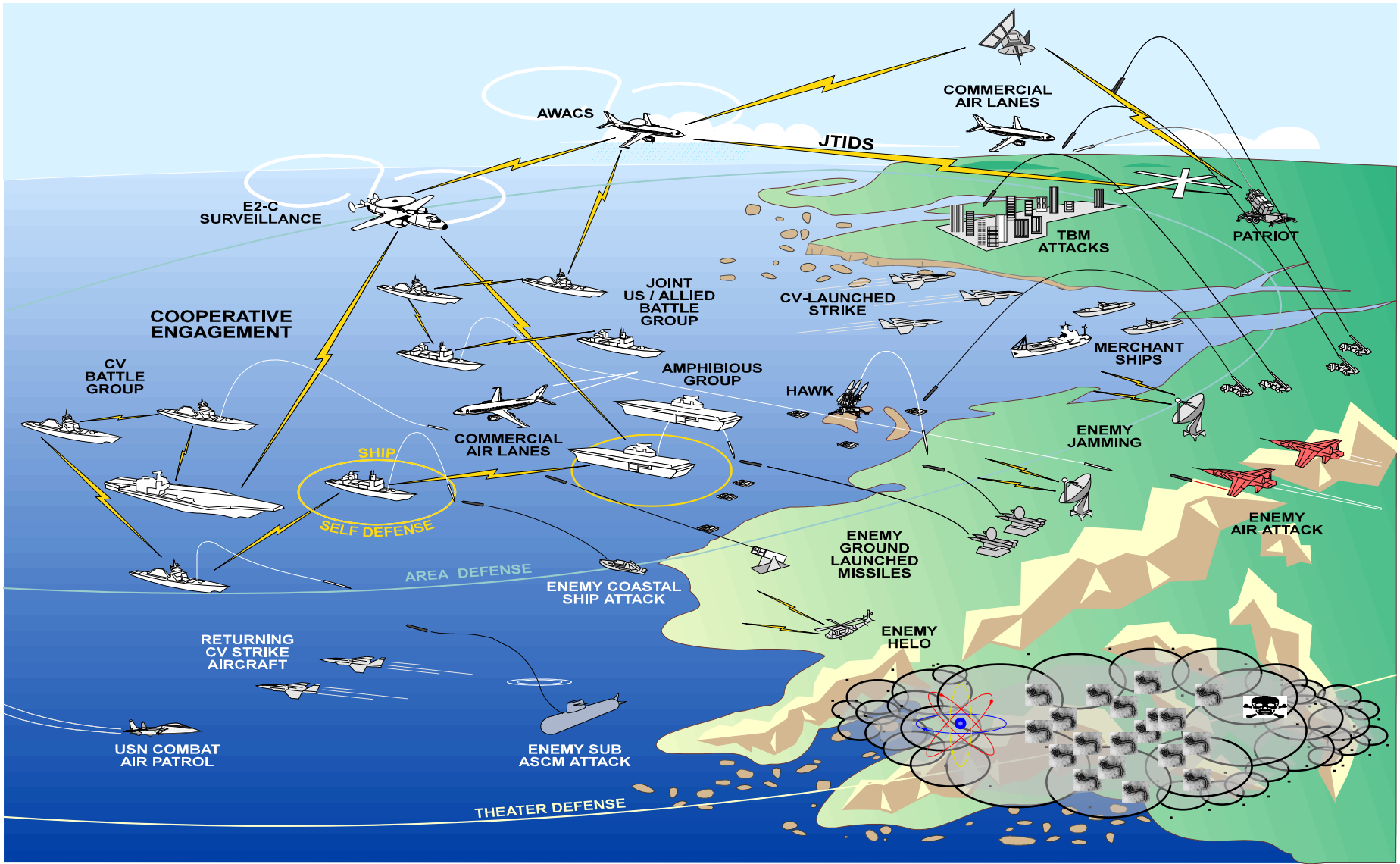
IPPD in an Evolutionary Environment

- Get testers onboard early to look at how each spiral is tested
  - Is evolutionary more cost effective?
- Logistics needs to be able to support multiple configurations
- Manufacturing processes should be designed to accommodate change

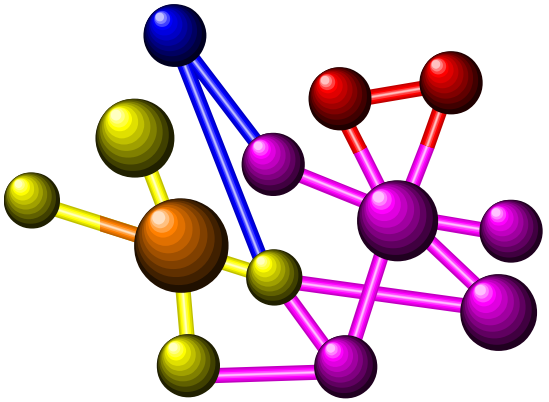
EA and Systems Engineering

- Spiral Development requires a solid systems engineering process for success
  - Requirements Development
  - Trade Studies
  - Risk Management
  - Configuration Management
  - Architecture Development
  - Interface Management

The Modern Battlespace Envir



Architecture What is it?



- **The structure of activities or components, their interrelationships, and the principles and guidelines that govern their design and evolution over time. May be logical or physical.**
- **The engineering vision that defines the engineering definitions and allocations to follow.**
- **Consists of different views of a common object or system. A single architecture has multiple views.**

Integrated Architecture: One Architecture - 3 Views

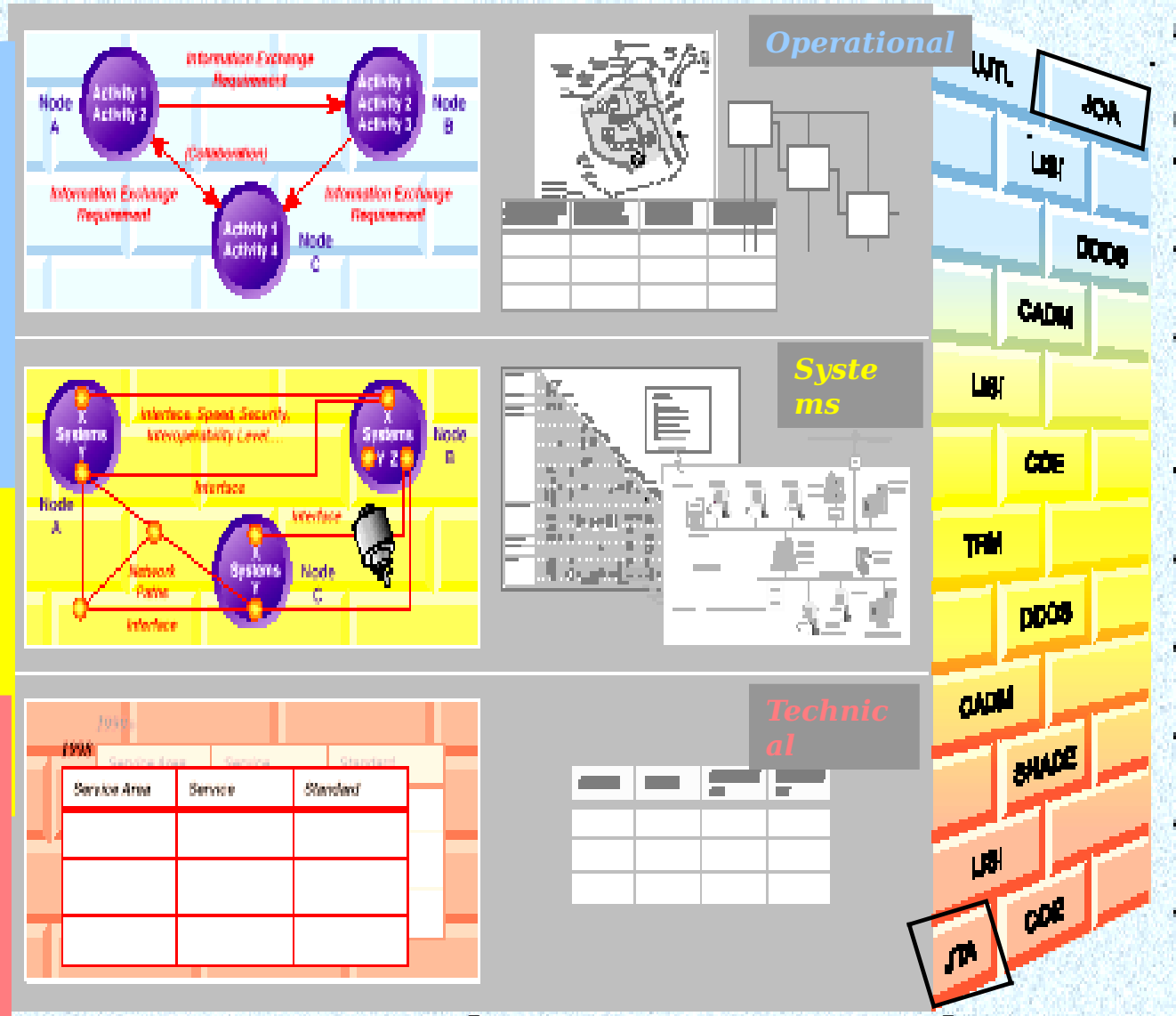
The Operational View

describes and interrelates the operational elements, tasks and activities, and information flows required to accomplish mission operations.

interrelates the existing or postulated technologies, systems, and other resources intended

The Technical View

describes the profile of rules, standards, and conventions governing systems implementation.



Source: C4ISR Architecture Framework

Design for Product Evolution

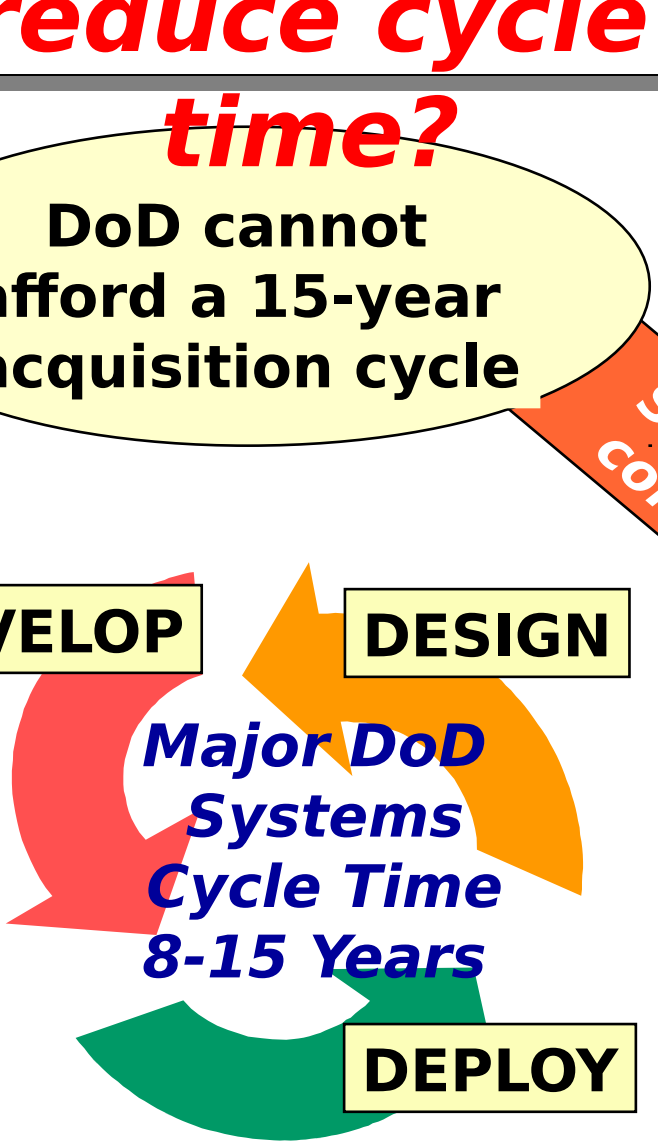
- Plan From The Beginning
- Focus: Make It Easy To Modify
- Standard Interfaces
  - Compartmentalized Design
  - Modularity
  - Recognized Interface Standards (preferably commercial)
- Standard Components
  - Increases opportunities for COTS, NDI
- Emphasize Interface Control To Provide Inherent Upgrade Capability

Attributes of an Open System

- Standards are Commonly Available
- Multiple Sources of Supply
  - Acquire building blocks from several sources on continuing basis
  - DoD is one of many customers for these building blocks
- Technology Transparency
  - Replace building blocks (HW or SW) without redesign
  - Incorporate new technology as it comes to market
- Lower life cycle cost for weapon systems
- Better performing systems with

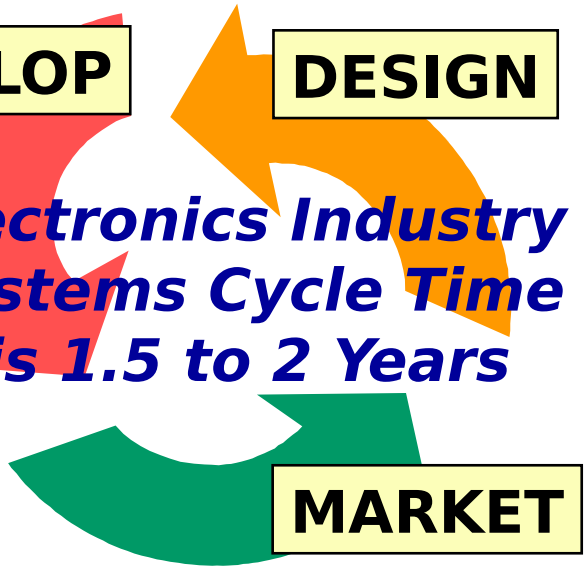
Why do we need to reduce cycle time?

DoD cannot afford a 15-year acquisition cycle



Major DoD Systems Cycle Time 8-15 Years

Supporting technology is constantly evolving



Electronics Industry Systems Cycle Time is 1.5 to 2 Years

Commercial market incorporates new technology 4 to 8 times faster

Radar Displays

Old display
welded to deck
Monochromatic
Big and heavy

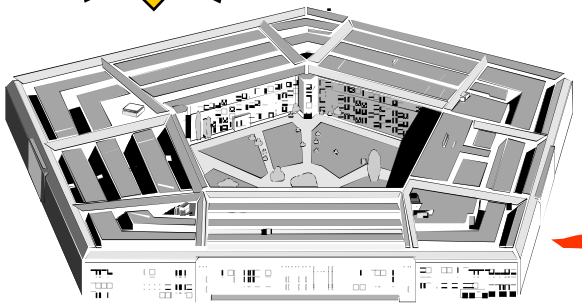
Commercial Display
Color picture
Rack mounted
Unit protection in shock mounts

Why Open Systems Are So Important

2000

DEVELOPER & USER

1950



DEVELOPER & USER

DOD no longer "drives" development. Instead, it must what industry has developed for commercial applications.

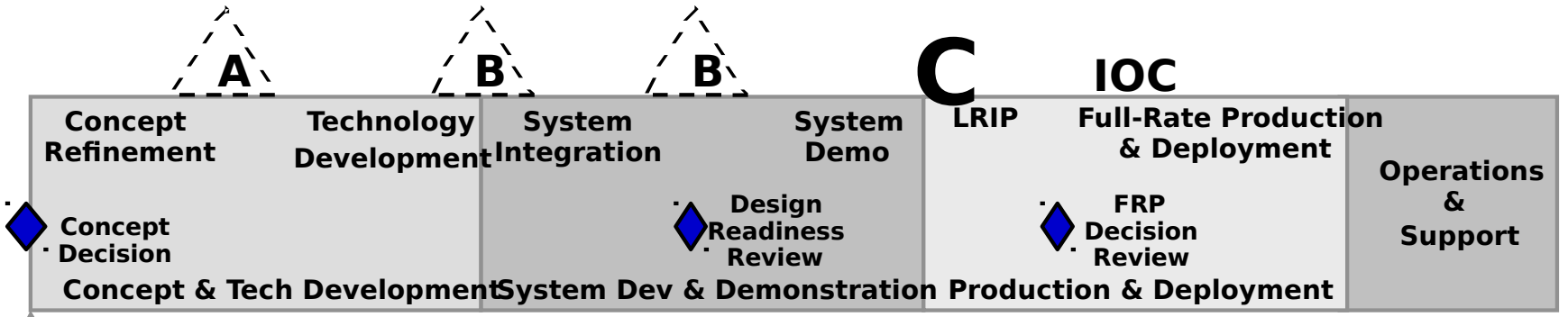
Technology Transition Program Manager's Perspective

- How mature is the technolo
- What are the risks?
- What are the payoffs?
- Cost and schedule?
- Where to enter the acquisition cycle?

Technology Insertion

Research (TRL 1) **Technology (TRL 2)**	**Remain in S&T or Concept Explora**
Proof of concept (TRL 3) **Components validated in lab (TRL 4)**	**Component Advanced Development**
Components validated in relevant environment (TRL 5)	**System Integration**
System/subsystem model demonstrated in relevant environment (TRL 6)	**System Demonstration**
System prototype demonstrated in an operational environment (TRL 7)	**Milestone C**

S&T Linkage to Defense Acquisition Proce



(1) (2) (2) (3) (3) (4)

Warfighting Needs & R&D Objectives

Systems

S&T

MDA DECISION

oversight panel

oversight panel

Adv Tech Dev (6.3)

- ACTD
- ATD
- Lab/field demo
- Warfighting Experiments

STOP

Tech Base (6.1/6.2)

- Basic Research
- Applied Research

STOP

Options

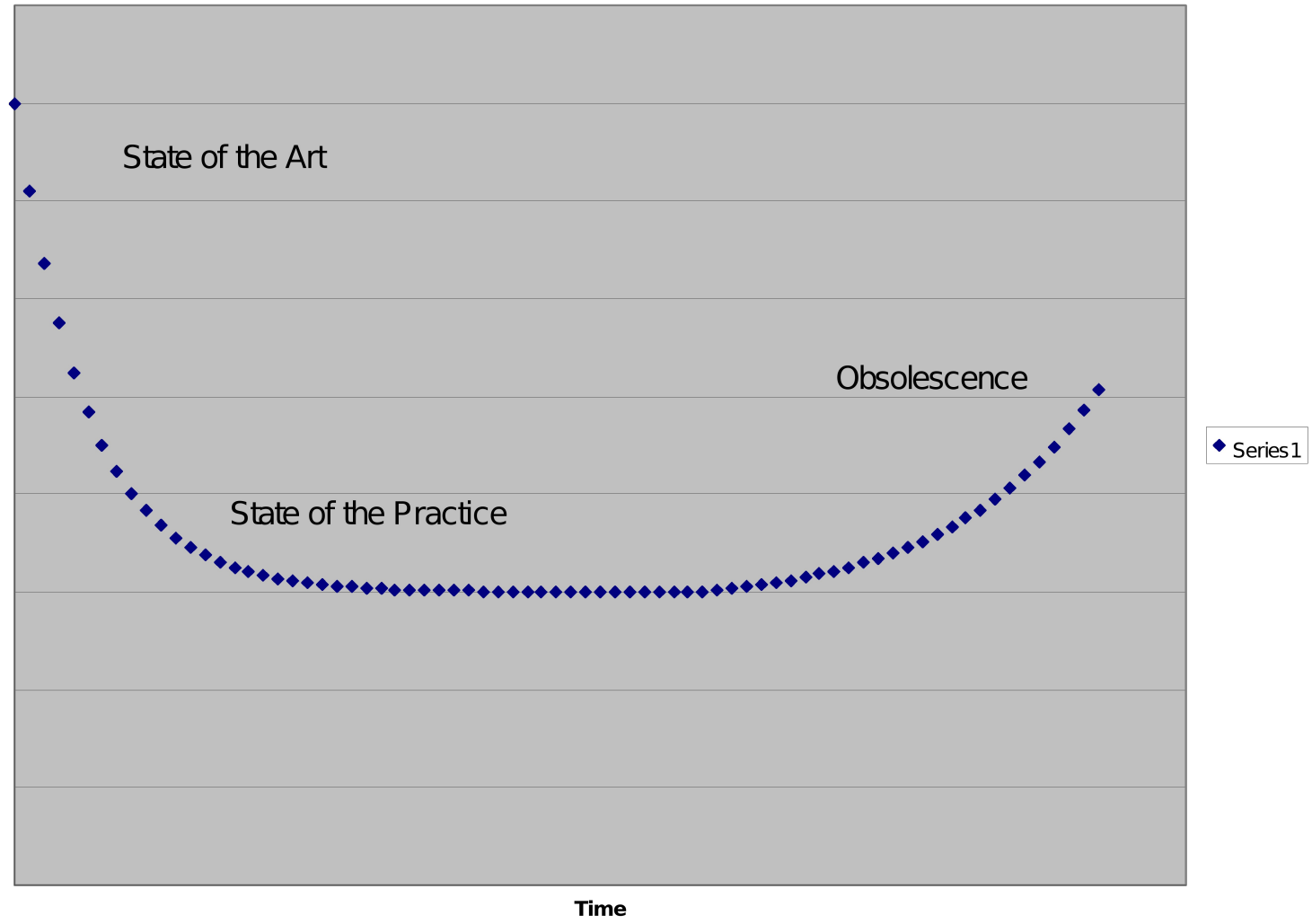
(1) Concepts for new systems/ upgrade systems out of production.

(2) Insert into ongoing systems development, or complete ACTD development.

(3) Upgrade system in production/ fielded systems or produce matur ACTD.

(4) Use of new technology for demilitarization/disposal.

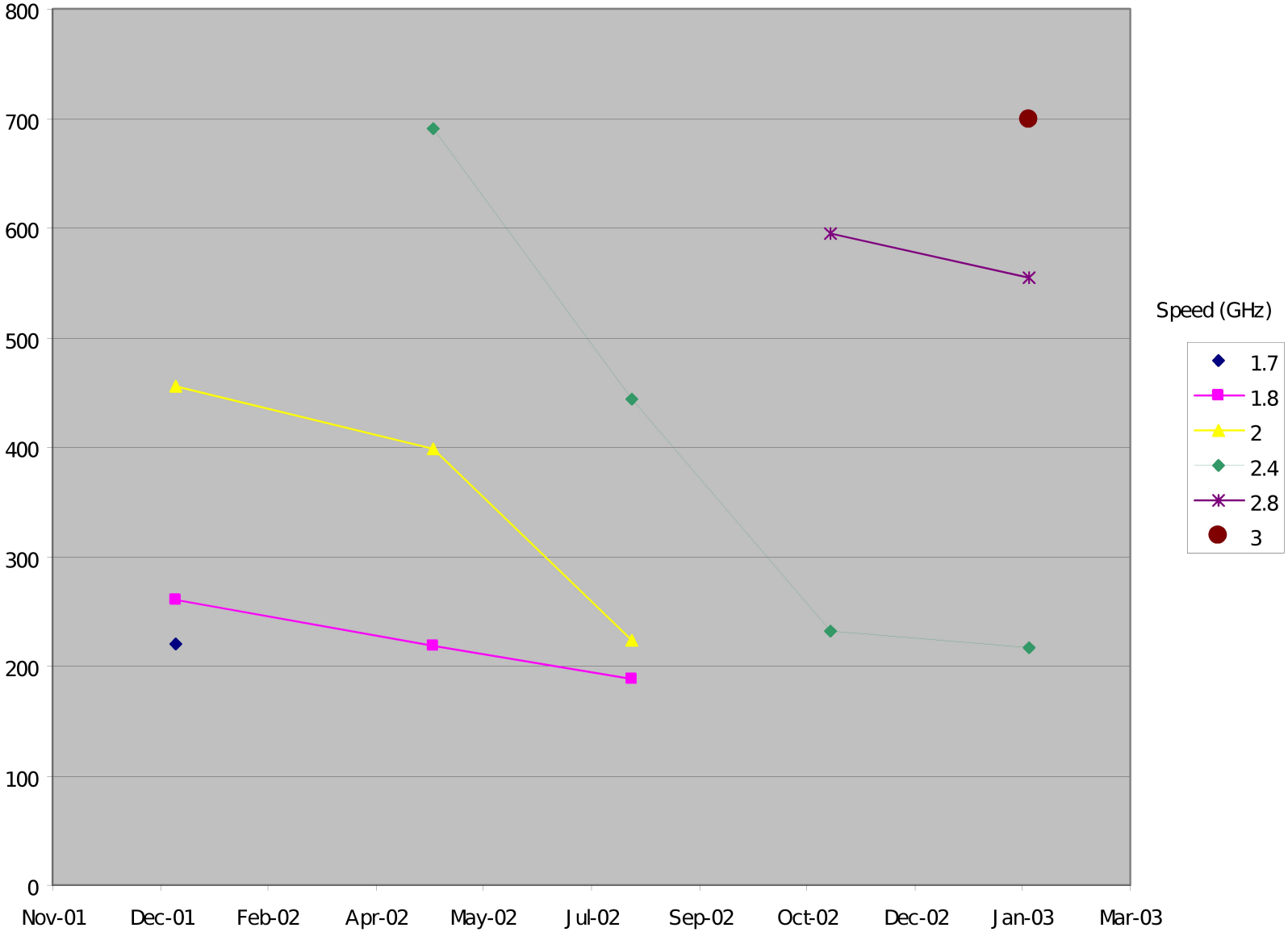
Technology Cycle



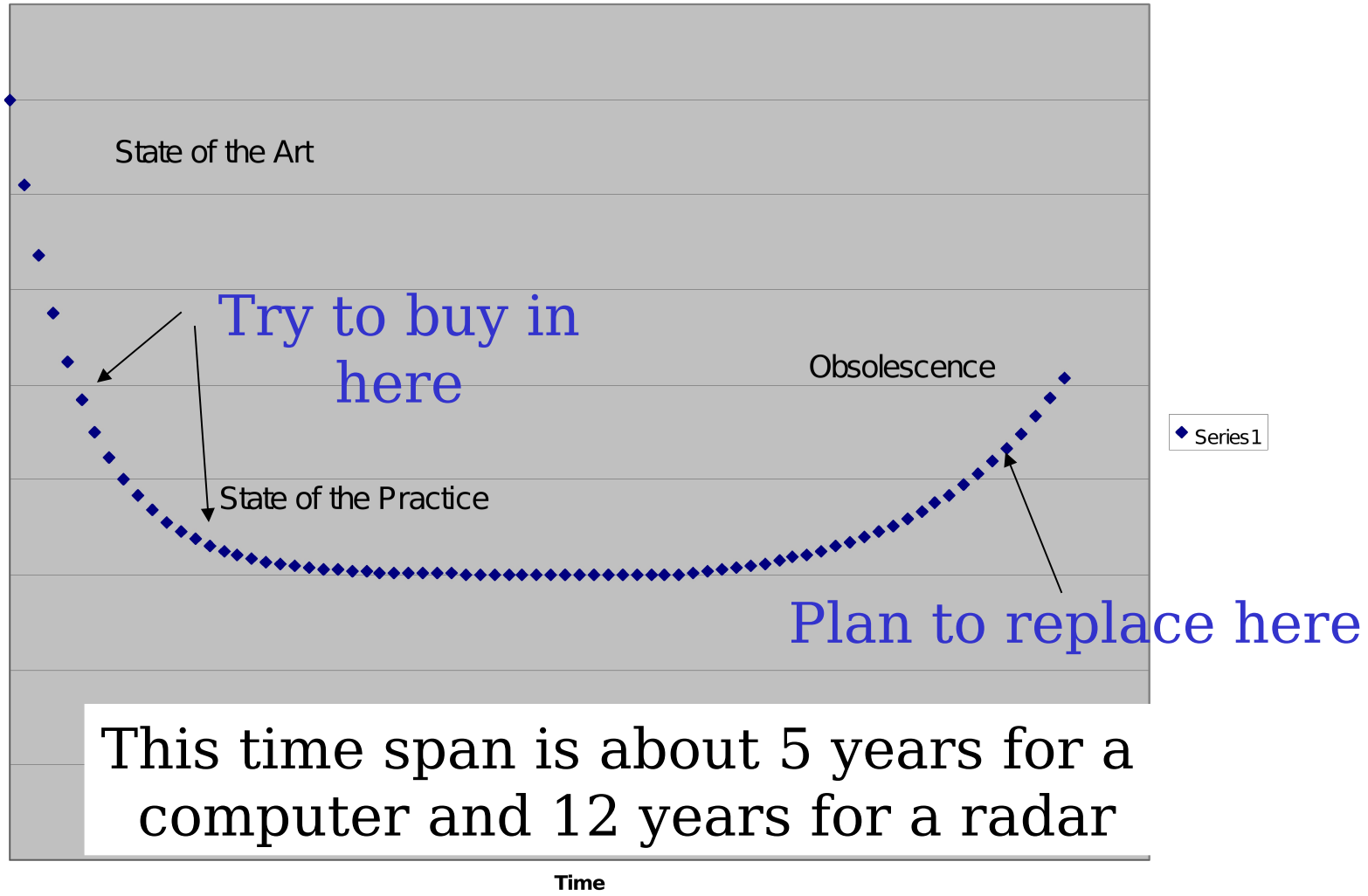
Technology Cycle

- State of the Art
  - New, cutting edge technology
  - Best Available
  - Few manufacturers in the market
  - Production processes still being worked
  - Scarcity of supply
  - High Cost
- State of the Practice
  - Mature technology
  - Multiple manufacturers
  - Production learned out
  - Lean manufacturing implemented
  - Plentiful Supply
  - Low Cost
- Obsolescence
  - Old technology
  - Major manufacturers leave the market
  - Niche suppliers move in
  - Manufacturing in small batches
  - Quantities more difficult to find with time
  - Higher costs

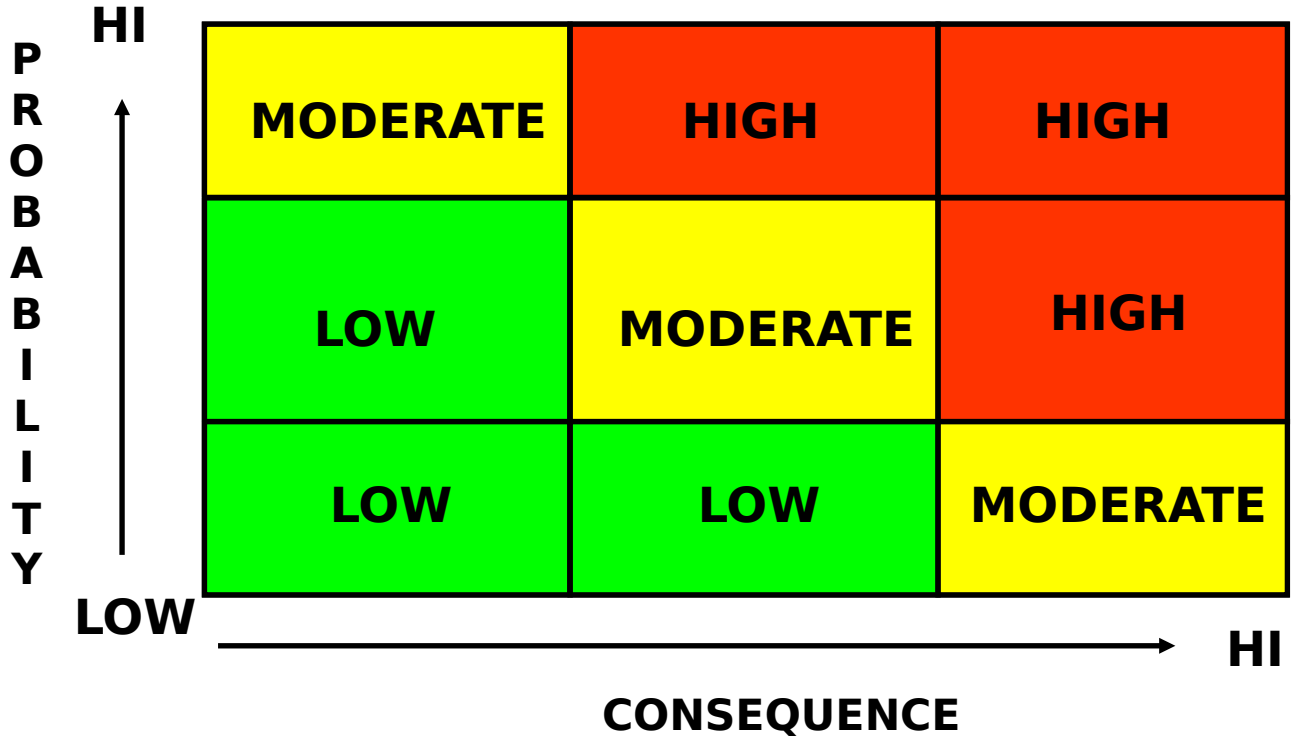
CPU Prices


800
700
600
500
400
300
200
100
0
Nov-01
Dec-01
Feb-02
Apr-02
May-02
Jul-02
Sep-02
Oct-02
Dec-02
Jan-03
Mar-03
Speed (GHz)
1.7
1.8
2
2.4
2.8
3

Technology Refreshment



Determining Technology Risk

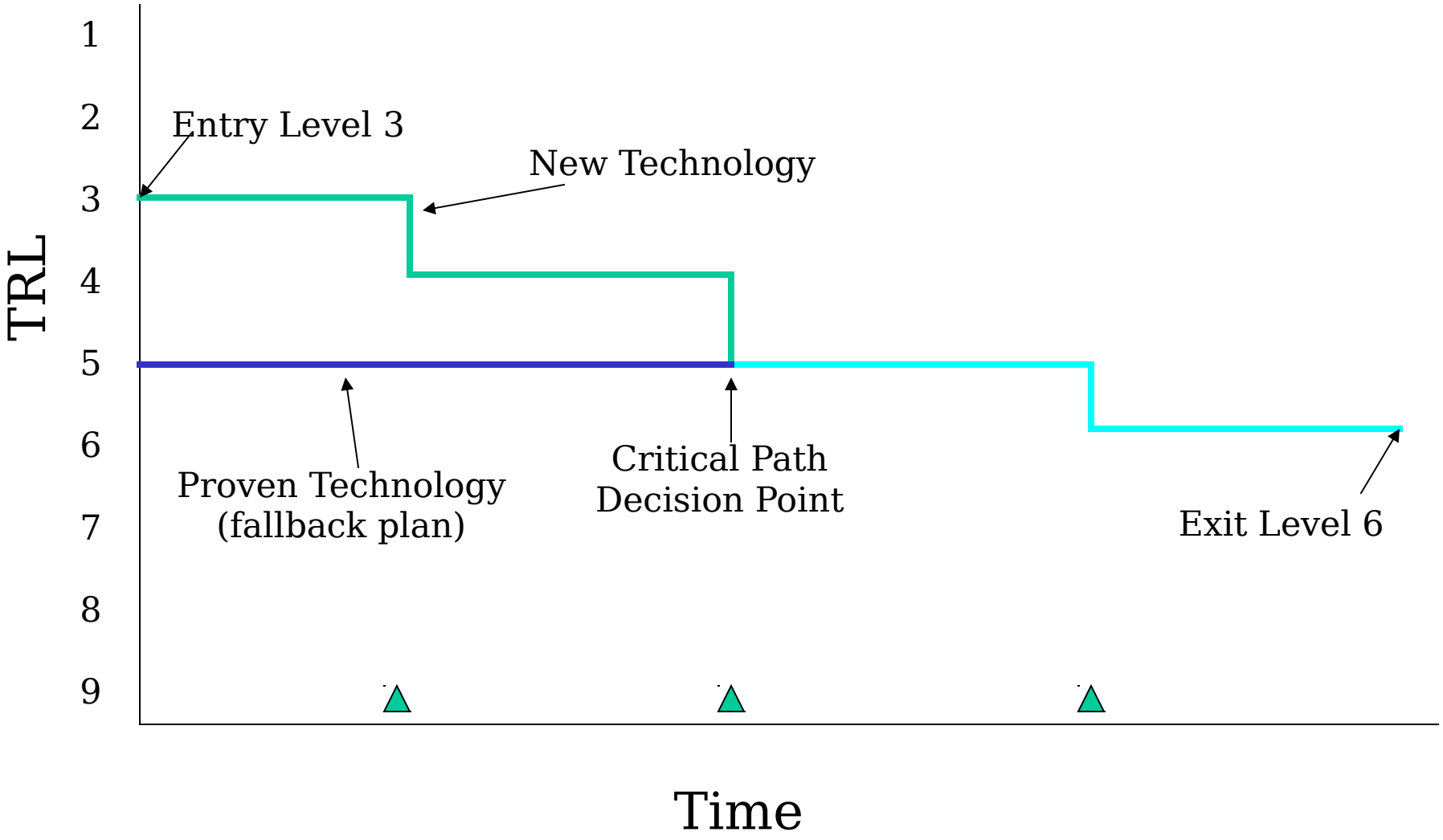


Technology risk is a function of the probability that a t
will not deliver its expected benefit and the consequer
system of not achieving that benefit

Risk Mitigation

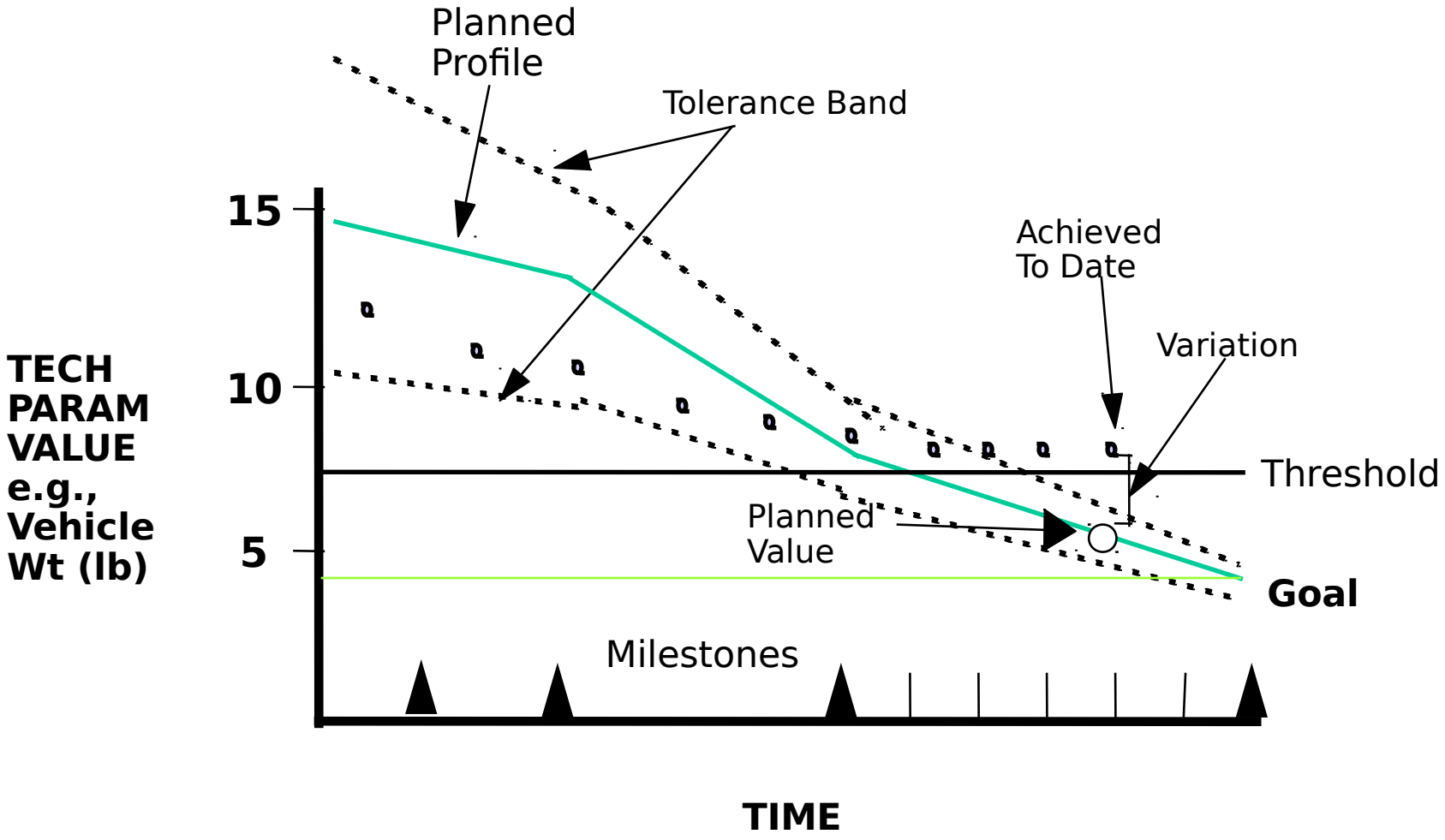
- Can Take Many Forms
  - Budget Reserves for unplanned activities
  - Concurrent Design Techniques
  - Solid technical management (TPMs, EVM, CM, Tech Reviews, etc.)
  - Integrated Tools, Automated Tools
  - Balanced Designs - Cost, performance, supportability, producibility trades
  - Disciplined Systems Engineering application
  - Bottoms Up Testing

Technology Risk Reduction Plan

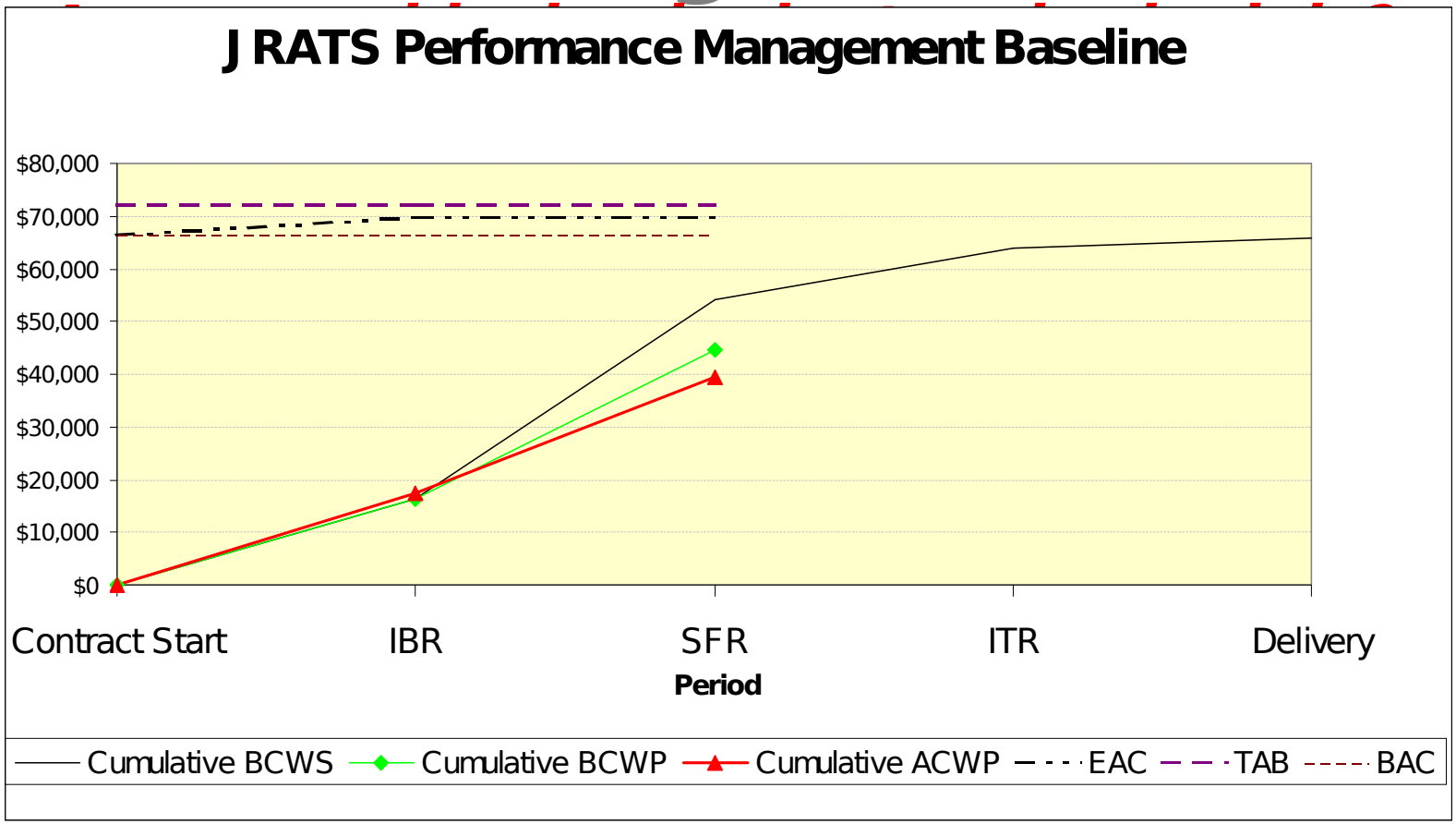


Technical Performance Measurements

Are you achieving performance on schedule?



Earned Value Management



Cost Challenges

- Cost Estimation
  - Difficult to estimate the cost when requirements and technologies are evolving
  - How much will the full capability cost?
  - Color of money
    - Parts of the system may be in development, production, operations and support simultaneously
- Funding stability
  - Commitment to follow-on blocks
- Full funding policy

Cuts in VA-class R&D pay for multiyear EOQs

NG CITES PROGRESS IN BLOCK BUY TALKS, BUT DIFFERENCES REMA

Date: March 31, 2003

With less money for R&D, the spiral development of the Virginia-class program's technology would not progress as quickly, he said. Asked if the Navy would bring the R&D numbers back up, Mullen said it would evaluate the impact on the program, concurrent with a Navy-wide R&D assessment that is intended to make sure that the dollars are going to the right places.

“When you remove resources, you're going to slow down the advancement or the insertion, in this case, of the technology that you planned,” Mullen said. “[In] this budget, as in all budgets, there are very difficult tradeoffs that needed to be made.

Fundamentals of EA/SD Cost Behavior

- EA & SD do not avoid the cost of requirements and technology change over the system development cycle
- EA & SD require a substantial investment in process management, with attendant overhead costs
- EA & SD program measures may depart significantly from traditional software measures
  - Productivity measures
  - Expenditure profiles (colors of money)

Cost Implications of Spiral Development

- First, understand the expected output
  - Full-up product, or define/refine requirements
  - For both instances, effort is expended and costs are incurred for non-deliverable interim products
- Second, understand the process
  - What resources are committed to each spiral?
  - What are the exit criteria for each spiral?
  - How many iterations are expected for a given set of functionality?
- Then, tailor the estimating methodology to the product and process
  - No school book solutions--Sorry.

Cost Implications of Spiral Development

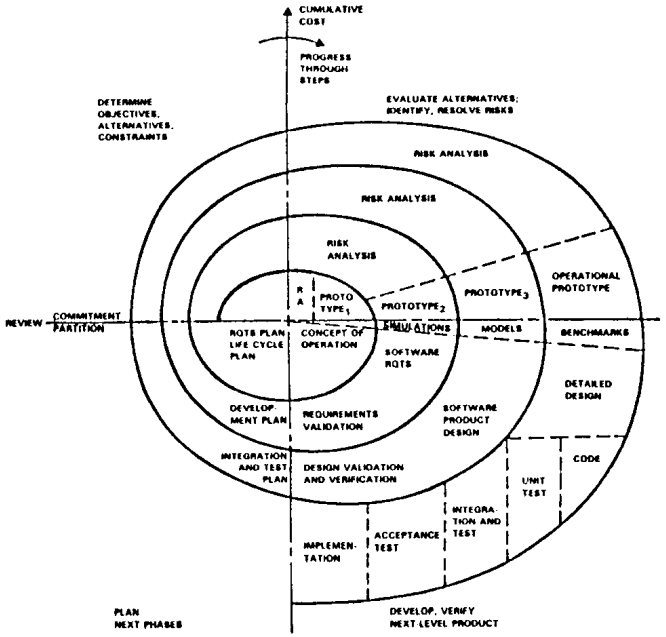
- First, understand the expected output
  - Full-up product, or define/refine requirements
  - For both instances, effort is expended and costs are incurred for non-deliverable interim products
- Second, understand the process
  - What resources are committed to each spiral?
  - What are the exit criteria for each spiral?
  - How many iterations are expected for a given set of functionality?
- Then, tailor the estimating methodology to the product and process
  - No school book solutions--Sorry.

Estimating SD: Possible Approaches

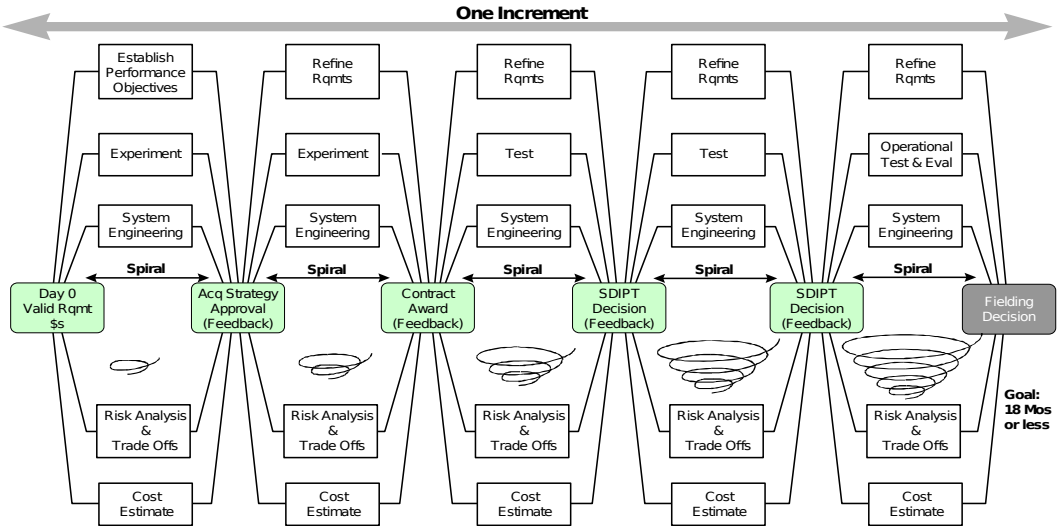
- Approach 1:
  - Start with size estimate of final delivered product; Crank in a scale factor for each spiral [e.g. Prototype LOC = DSI (0.3+0.6+0.9+1.0)],
  - Assume reuse ratios for each spiral.
- Approach 2:
  - "Unroll" the spiral (see diagram on chart 8), and estimate the effort/cost of each element and activity.
- Approach 3:
  - If SD is only used for risk reduction (no deliverable software)
  - Assume Level-of-effort (# staff months times development duration).
- Use these in combination to cross-check

Spiral Model

A: Boehm's Spiral Model



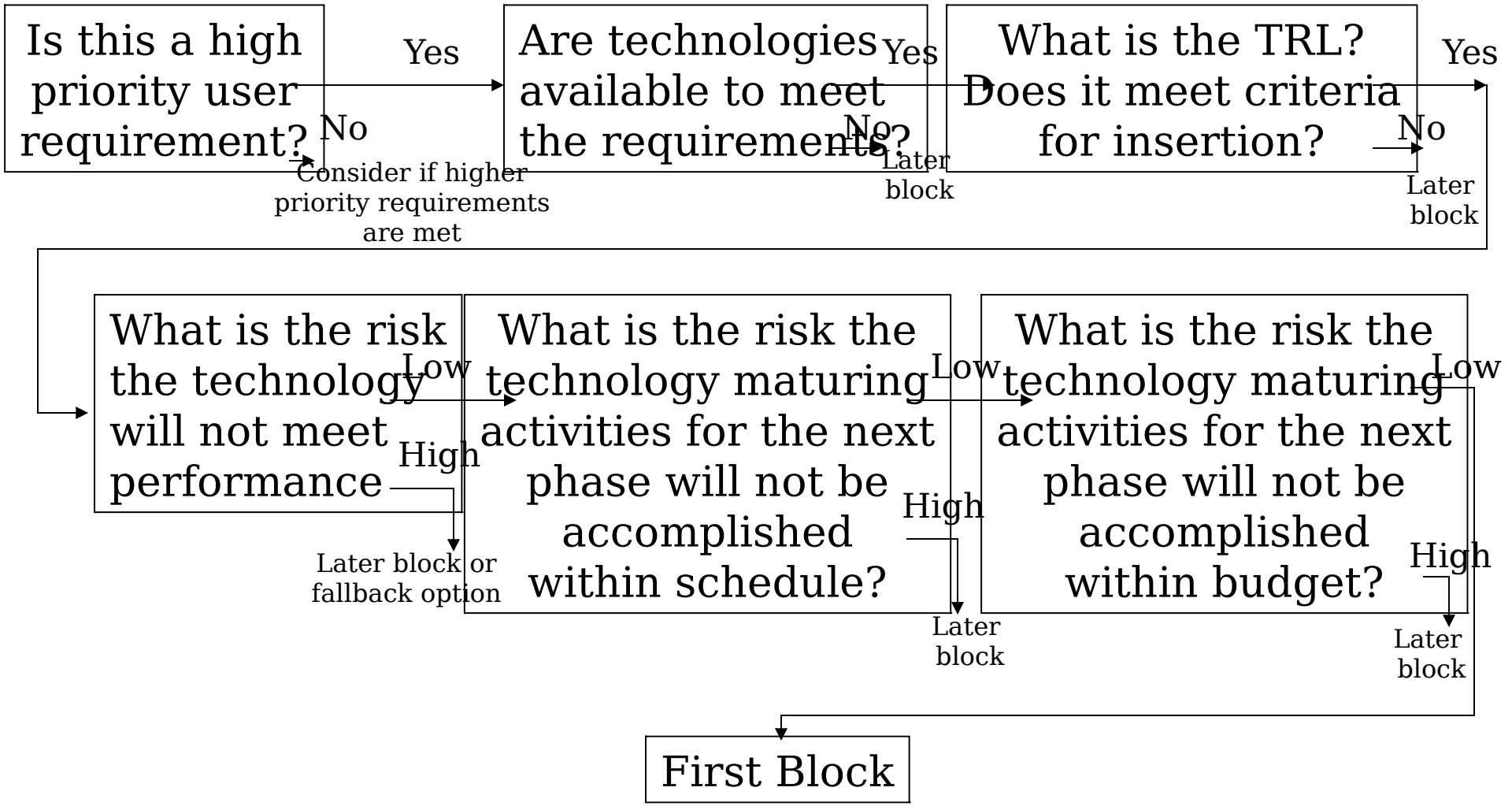
B: The "Uncoiled" Spiral



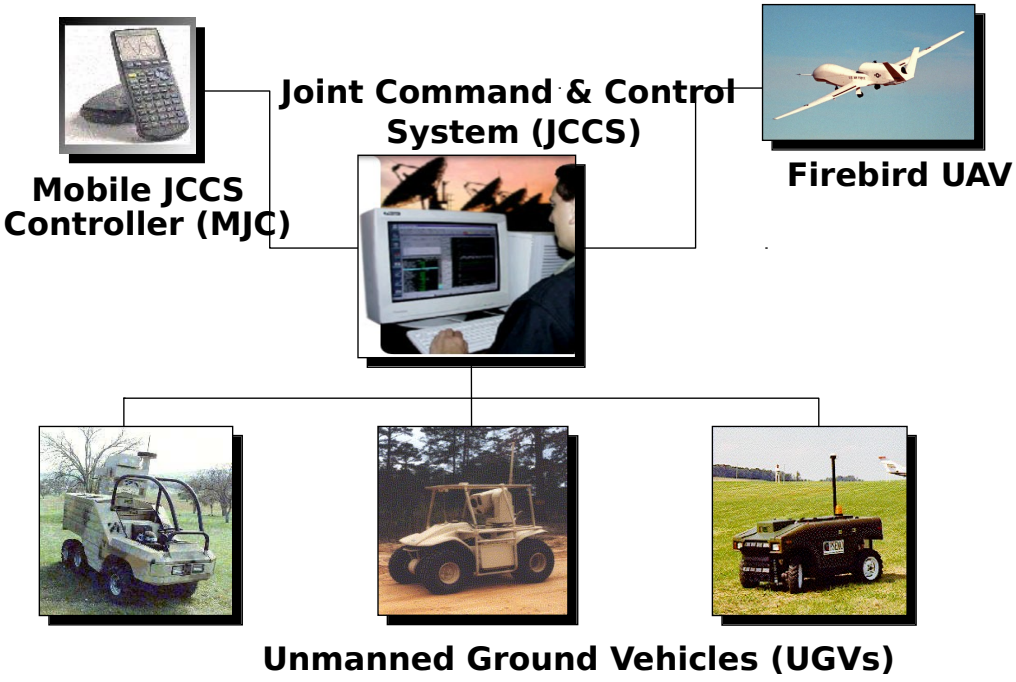
A: Boehm, B., "A Spiral Model of Software Development and Enhancement." *IEEE Computer* (May 1988): 61-

B: McNutt, R., "Reducing Air Force Acquisition Response Times: Evolutionary Acquisition and Spiral Develop U.S. Air Force Briefing, 13 Sept 2000

Building an Evolutionary Strategy



PMT-352 Spiral Development Exercise



- Future based program
- Choose from existing UGVs
- Arm for attack mission
- Technology insertion into existing systems
- Interoperable with UAV and

Joint Reconnaissance and Autonomous Targeting System

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- Program Management Communities of Practice
  - Risk Management
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  - Contracting
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  - Logistics
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- Data Management
- Environment, Safety & Occupational Health
- Earned Value Management
- Information Technology
- Performance-Based Service Acquisition
- Production Quality & Manufacturing
- Spectrum Compliance
- Total Ownership Cost

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What's New

New OUSD Policy for Systems Engineering
Effective immediately and to be included in the next DoD 5000 series, programs shall develop a Systems Engineering Plan (SEP) for Milestone Decision Authority approval in conjunction with each Milestone review and integrated with the Acquisition Strategy. **FLASH!** Interim guidance on implementing the SEP requirement was approved 30 March 2004. *[revised 13 Apr 2004]*

In the Spotlight

New PQM SIA!
Our newest Special Interest Area, Production, Quality and Manufacturing (PQM), has information on Global Manufacturing, Lean Techniques, Six-Sigma, Supply Chain Management, and much more. Check it out! *[6 Apr 2004]*

New! System Safety Area
System Safety applies the engineering and management principles, criteria and

ticipate

Join a Discussion (17)

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tors of this Topic

Mr Peter Reinhardt

Special Interest Areas:

- System Safety
- Standardization
- Modeling & Simulation
- Evolutionary Acquisition
- Test & Evaluation
- Requirements
- Human Systems Integration
- Software Acquisition
- Production Quality & Manufacturing

Features

- "New" SE Policy in DoD dated 2 February 2004
- Lean-Six Sigma Continuous Learning Module
- SEI Perspectives on Open Sou Software (OSS)
- Top 10 vulnerabilities in Web applications and services
- Implementing Systems Engine Plans in DoD
- Probability/Consequence Softv (P_CS) V4.2.5

NDIA Education & Training Summit: "Focusing on Syste Engineering"
2003-10-01 12:40 pm

Bridge the Gap (1)
Should we, and the acquisiti
Dr. James Dobbins 2003-11-1:21 pm

CJCSI 3170.01D, dated 12March2004 (1)
Requirements Generation is
Dave Brown 2003-01-27 2:2

What's New

- Implementing Systems Engine Plans in DoD
- Acquisition Update

RE: "Robust" Systems Engineering
http://cse.afit ...
Dr. Angelica Trzepacz 2004-04 3:59 pm

http://www.pmcop.dau.mil/pmcop/kcontributions/211_HW_TRL_Versi

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Address http://www.pmcop.dau.mil/pmcop/kcontributions/211_HW_TRL_Version_1_1.xls | Go | Links

A1

AFRL Hardware TRL Calculator Version 1.1

Enter Data for Hardware TRL

Hardware TRL Definitions

AFRL Comments

Color Code

Save No Exit

Exit No Save

Save & Exit

Version

Title | TRL Definitions | AFRL Comments | Calculator | Version | Colo

Unknown Zone

Depot System-Consequence Screening Matrix

3/7/2000

	NEGLIGIBLE	MINOR	MODERATE	SERIOUS	CRITICAL
Level 5: 91 - 100%				P11A, S11A, P21A, S21A	
Level 4: 61 - 90%			C1B, S11B, S21B	S1B, P11B, P11D, S11D, P21B	P1B
Level 3: 41 - 60%	P2A, P2B	S2A, C2A, S2B	P11C, P12A, S12A, S14A	P11G, S11G, P14A	
Level 2: 11 - 40%		S4, S11F, S12B, P24A, S24A, P24B, S24B	S11E, P11F, P12B	P11E	
Level 1: 0 - 10%		P3			

OK

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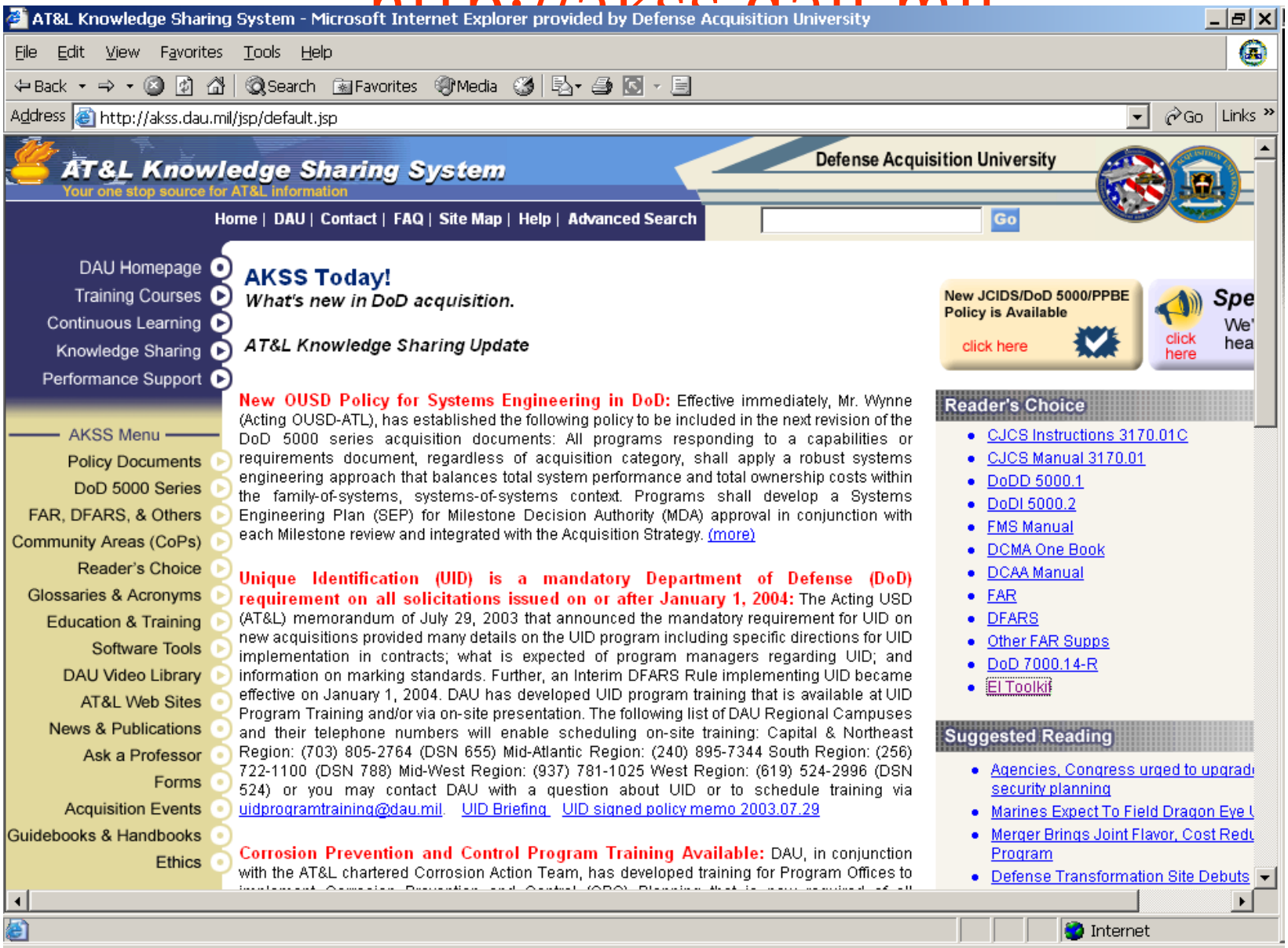
?

Legend

Requirements	Risks
1 RFO	1B No engineer assigned
2 Radar Receiver	2A No plan to get to QOT&E
	2B Avalibility of resources to close STR
3 Interface Blanker	
4 IFF	
11 Radar D/P	11A Non-Detects & incorrect isolation
	11B TPS not complete
	11C Lack of documentation
	11D ITA2 wiring changes
	11E SVTP
	11F Fault isolation
	11G LRU architecture does not support FI
12 A/D Converter - MSIP 038	12A SCT not complete
	12B STRs not closed
14 Radar Target DP	14A ITA migration
21 PSDP	21A Envirnomental testing of COTS monitor

New Defense Acquisition Deskbook

http://akss.dau.mil



Evolutionary Acquisition Summary

- Delivers initial capability to the user in a shorter time period
- Improves technology available to the user in the final product
- Cost reduction is through cost avoidance associated with poor requirements, infeasible solutions and rework
  - Up front planning and overhead management will be more
- Good Systems Engineering processes and sound technical management plans are essential for success